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CHEMISTRY.—*The separation of isotopes by chemical means.*[1] HAROLD C. UREY, Columbia University. (Communicated by FRED L. MOHLER.)

Ten years ago no successful separation or even extensive concentration of the isotopes of any of the elements had been made. Methods for the separation of isotopes that had been suggested and investigated depended upon differences in the physical properties of isotopes and isotopic compounds which were readily predictable from simple kinetic theory, as, for example, separation by diffusion through porous tubes and by unidirectional evaporation. Today several methods are available for the concentration of isotopes, and the isotopes of a few elements have been separated quite completely. It is my purpose here to review the present status of this problem, and particularly to emphasize the part of the problem with which my colleagues and I have been most closely associated.

In 1931 two successful attempts at the partial separation of isotopes were made. The first of these, by Keesom and van Dijk,[2] dealt with the separation of the isotopes of neon by the fractional distillation of liquid neon. The second of these was the concentration of the rare isotope of hydrogen by Brickwedde, Murphy, and myself,[3] in connection with our experiments leading to the discovery of this isotope. These distillation methods could be predicted from current theories in regard to the solid state and were independently predicted by these two groups of authors. Recent work by Keesom, van Dijk, and Haantjes[4] has produced rather high concentrations of the neon isotopes in substantial amounts, and Scott and Brickwedde[5] have prepared hydrogen deuteride, HD, in nearly a pure form by the fractional distillation of a mixture of hydrogen, deuterium, and hydrogen deuteride.

[1] The Tenth Joseph Henry Lecture of the Philosophical Society of Washington, delivered on March 16, 1940. Received April 19, 1940.
[2] KEESOM, W. H., and VAN DIJK, H. Proc. Acad. Sci. Amsterdam **34**: 42. 1931.
[3] UREY, H. C., BRICKWEDDE, F. G., and MURPHY, G. M. Phys. Rev. **40**: 1. 1932.
[4] KEESOM, W. H., VAN DIJK, H., and HAANTJES, J. Proc. Acad. Sci. Amsterdam **37**: 615. 1934; Physica **1**: 1109. 1934.
[5] SCOTT, R. B., and BRICKWEDDE, F. G. Phys. Rev. **48**: 483. 1935.

Differences in vapor pressures of deuterium and protium oxides, the O^{16} and O^{18} waters, and the N^{14} and N^{15} ammonias, as well as similar differences in the cases of many of the isotopic compounds of hydrogen, are now known and have been used to concentrate the isotopes of oxygen and hydrogen by fractional distillation methods. These differences in vapor pressures are small, and effective separation can be made only by very efficient fractionation columns.

The first complete separation of isotopes was accomplished by means of the electrolytic separation of the hydrogen isotopes, discovered by Washburn.[6] This method of separation is so effective and so easily carried out, and the demand for the heavy isotope of hydrogen so general, that deuterium and its compounds are now produced commercially by this method.

In 1932 Hertz[7] developed his cascade diffusion method, making use of a series of diffusers arranged in a cascade, so that the light fractions diffusing through the porous tubes, or through a moving stream of mercury vapor, were fed to a preceding unit of the cascade, while the heavy fractions were fed to the following unit of the cascade. In this way Hertz prepared nearly pure neon isotopes and also succeeded in preparing very pure samples of deuterium. Others have used this method to concentrate other isotopic substances.

In 1935, Urey and Greiff[8] presented a method for the separation of isotopes by chemical means, depending upon the slight differences in the chemical properties of isotopic compounds. This method has since been developed and has led to the separation of nitrogen and carbon isotopes in substantial amounts.

Recently Clusius and Dickel[9] discovered the thermal diffusion method, which is applicable to many gaseous substances. The method has many interesting features and undoubtedly can be used widely for the separation of small amounts of rarer isotopes.

Recently Beams[10] has made some orienting experiments on the centrifugal fractionation column method. These have not gone so far as to produce separated isotopes, but they have demonstrated the feasibility of the method.

Smith and Scott[11] have investigated the possibility of using oscillating electric fields acting upon streams of ions as a means of separating isotopes. The difficulty of mass spectrographic methods and these al-

[6] WASHBURN, E. W., and UREY, H. C. Proc. Nat. Acad. Sci. **18**: 496. 1932.
[7] HERTZ, G. Zeit. Phys. **79**: 108, 700. 1932.
[8] UREY, H. C., and GREIFF, L. J. Journ. Amer. Chem. Soc. **57**: 321. 1935.
[9] CLUSIUS, K., and DICKEL, G. Naturwissenschaften **26**: 546. 1938.
[10] BEAMS, J. W., and SKARSTROM, C. Phys. Rev. **56**: 266. 1939.
[11] SMITH, L. P., and SCOTT, G. W., Jr. Phys. Rev. **55**: 946. 1939.

ternating field methods resides in the low intensity of beams of ions. Owing to the repulsion between the ions, the beams spread rapidly, and sharp separation can not be secured if large amounts of the separated isotopes are desired. Smith has found that it is possible to arrange an apparatus so that electrons are present in the beam with the ions, thus preventing the spread of the beam.

With all these methods available, or their development actively in progress, it appears now that the separation of the isotopes of the elements in amounts necessary for adequate physical, chemical, and biochemical research is only a matter of time. The past 10 years have brought the problem from a position where no separation had been secured to a point where the entire discussion is now based upon the best methods. The methods that my colleagues and I have developed, namely, the chemical exchange methods and distillation methods, appear to be those most suitable for large production of separated isotopes in the limited number of cases where they are applicable. It is the purpose of this lecture to discuss principally these chemical methods of separation for the elements carbon, nitrogen, and sulphur, and to compare this method with the others mentioned above.

THEORY OF THE SEPARATION OF ISOTOPES BY FRACTIONATION COLUMNS

The most common method for the separation and purification of substances used in chemistry is that of distillation, making use of fractionation columns. As mentioned before, this method was used for the concentration of the hydrogen and neon isotopes where the differences in vapor pressures could be readily predicted by the use of the Debye theory of the solid state. Early in the investigation of the properties of hydrogen and deuterium compounds, Lewis and Cornish[12] and Washburn, Smith, and Frandsen[13] observed that there were differences in the vapor pressures of hydrogen oxide and deuterium oxide, and it was also observed that there were slight differences in the vapor pressures of the O^{16} and O^{18} waters.

The theory of distillation apparatus has been discussed in standard textbooks for many years, and little new can be added. However, there are certain points to be emphasized when one comes to the fractional distillation of substances with only slight differences in vapor pressures. The simple process fractionation factor may be defined as the ratio of the two constituents in the vapor divided by this ratio in

[12] LEWIS, G. N., and CORNISH, R. E. Journ. Amer. Chem. Soc. 55: 2616. 1933.
[13] WASHBURN, E. W., SMITH, E. R., and FRANDSEN, M. Bur. Standards Journ. Res. 11: 453. 1933.

the liquid phase. Letting N and n represent the mole fraction of one constituent in the liquid and the vapor, respectively, this fractionation factor α may be defined by the equation

$$\frac{n}{1-n} \Big/ \frac{N}{1-N} = \alpha. \tag{1}$$

The fractionation secured by a column is then given, according to reasonable theory (see below) as well as experiment, by the formula

$$\frac{N_t}{1-N_t} \Big/ \frac{N_b}{1-N_b} = \alpha^{kz}, \tag{2}$$

where N_t and N_b are the mole fractions of one constituent at the top and bottom, respectively, α is the simple process fractionation factor defined above, z is the length of the column and k is a constant. The quantity kz is referred to as the number of theoretical plates. In the case of the plate columns, common for many distillation processes in the chemical industry, the plates are actual physical plates, although each may not change the ratio of the two constituents by the simple process factor. In the case of packed columns, which have been developed in recent years in considerable variety, no physical plates are present in the column but the fractionation follows this exponential form, as determined by experiment. It is of considerable interest to derive expressions by which the time required for equilibrium to be established can be calculated at least approximately. Such a calculation was made by Huffman and Urey[14] for the case of total reflux with a large reservoir at one end of the column. The formula secured by them is

$$N_0 ln \frac{N_0}{N} + (1 - N_0) ln \frac{1 - N_0}{1 - N} = \left(\frac{LN_0(\alpha - 1)kz\, ln\alpha}{H}\right)t \tag{3}$$

where H is the holdup of the column per unit length, N and N_0 are the mole fractions of one constituent at the reflux end at time t, and in the natural substance, respectively, and L is the rate of flow through the column. This formula shows that in order to secure a rapid equilibrium, a small holdup, large natural abundance, rapid rate of flow, and a fractionation factor that deviates markedly from unity, are required. In the distillation of isotopic substances and their separation by chemical exchange methods, however, the value of the simple process factor is very nearly unity, and the time required to reach a steady state may be very long indeed unless a column of proper design is

[14] HUFFMAN, J. R., and UREY, H. C. Ind. Eng. Chem. 29: 531. 1937.

secured. This means that columns with small holdup, rapid rate of flow, and a large number of theoretical plates per unit length are required. In most industrial processes, fractionation columns that have from 10 to 50 theoretical plates are quite adequate. However, if adequate separation is to be secured for isotopic molecules, a very large number of theoretical plates, e.g., from 300 to 500, is required. This large number is necessary because the ratios of vapor pressures of isotopic substances deviate only slightly from unity.

The transport of such apparatus is, of course, equal to the difference in the flow of one isotopic substance in the two directions. If the mole fraction of the isotope to be concentrated is small, the transport at the beginning of the operation of such a column, using total reflux, is given by the equation

$$T = LN_0(\alpha - 1) \tag{4}$$

where L is the total flow in either direction and N_0 the mole fraction of the rare isotope in the mixture. This formula is approximate and applies only when the fractionation column is not near the steady state.

A more exact theory of the operation of such columns can be given if one assumes that back diffusion is not an important process in the column, and that the rate of transport of material from the one phase to the other depends upon the concentrations in the two phases in the way required for the equilibrium process. Two differential equations can be secured for the rate of change of concentration in the two phases. These are:

$$H\frac{\partial N}{\partial t} - L\frac{\partial N}{\partial z} - k_1N(l - n) + k_{-1}n(l - N) = 0 \tag{5}$$

$$h\frac{\partial n}{\partial t} + l\frac{\partial n}{\partial z} + k_1N(l - n) - k_{-1}n(l - N) = 0 \tag{6}$$

where L, H, N and l,h,n are the rate of flow, the holdup, and the mole fraction in the liquid and gas phase, respectively, and k_1 and k_{-1} are the velocity constants for the transport of this isotope from one phase to the other. The solutions of these two simultaneous equations in a form suitable for convenient calculation have not been made. However, if we are interested only in the final steady state, so that the derivatives with respect to the time are zero, the solution of the equations is simple. The first integral is

$$LN - ln = n_0(L - l) \tag{7}$$

This equation states that the net flow in the column is equal to the amount of material withdrawn at one end of the column. The second integral leads to the following relation between the forward flow and the composition of the material produced:

$$y + \theta = (l + \theta y) \tan h \left\{ -\sigma(l + \theta y) + \tan h^{-1}\left(\frac{1 - 2N_0 + \theta}{1 + \theta y}\right)\right\} \qquad (8)$$

where $$y = l - 2n_0,\ \theta = \frac{l - L}{l - \alpha},\ \text{and}\ \sigma = \tfrac{1}{2} l n F_0.$$

In these equations n_0 is the mole fraction of the isotope in the forward flow and F_0 is the overall fractionation factor when the forward flow is zero. By making use of these equations it is possible to show how the effective fractionation factor for the column changes with the rate at which material is withdrawn. Our apparatus seems to give better results than the simple theory would indicate.

In the case of the fractional distillation of the hydrogen isotopes, the values of α are in the neighborhood of from 3 to 10, depending upon the temperature and whether one is working with H_2 and HD or H_2 and D_2. The distillation of the hydrogens is therefore a problem like that of the separation of ordinary substances, except that the fractionation must take place at a very low temperature. In the case of the fractionation of the hydrogen and deuterium oxides, however, or of the O^{16} and O^{18} waters, the ratios of the vapor pressures are nearly equal to unity, as shown in Table 1. In this case it may require long periods of time for the fractionation column to come to a steady state.

TABLE 1.—RATIO OF VAPOR PRESSURES OF WATERS

T °C	$p(H_2O^{16})/(pH_2O^{18})$	$p(H_2O)/p(D_2O)$
3.8		1.188
11.25	1.013	
20.0		1.148
23.0	1.008[8]	
35.6	1.008[2]	
40.0		1.115
46.35	1.007[7]	
80.0		1.070
100.0	1.003 (extrapolated)	1.052

CONCENTRATION OF OXYGEN ISOTOPES

Huffman and Urey[14] made a substantial concentration of the O^{18} isotope by means of distillation methods. Water was pumped in at the top of a fractionation column at a fixed rate, evaporated completely

at the bottom, and the vapor returned upward through the column. At the top, the vapor was discarded since it was not convenient to condense the water for re-use. In this way water containing 0.85 per cent O^{18} was produced, i.e., with somewhat over four times the natural concentration of O^{18}. Also, considerable amounts of water containing half the normal abundance of O^{18} were produced by boiling a large container of water at the bottom of the column and totally refluxing at the top. The operation of the column in this case was not steady and this probably accounts for the smaller change in the ratio secured.

It does not seem probable that distillation methods can be very useful in other cases for the separation of isotopic substances. The N^{14} and N^{15} ammonias have but slight differences in their vapor pressures, as is shown by Table 2. The great difficulty in carrying out a distillation at the temperature of boiling ammonia, using extensive

TABLE 2.—VAPOR PRESSURES OF THE AMMONIAS

T °K	$pN^{14}H_3$ (cm of Hg)	$pN^{15}H_3$ (cm of Hg)	$p(N^{14}H_3)/p(N^{15}H_3)$
197.75	5.488	5.459	1.0053
204.4	9.060	9.018	1.0046
207.1	10.904	10.858	1.0042
208.8	12.593	12.541	1.0041
217.2	21.570	21.488	1.0038
228.2	41.030	40.899	1.0032
228.4	41.550	41.418	1.0032
234.9	59.560	59.399	1.0027
239.4	75.340	75.153	1.0025

fractionation columns, makes this an unsatisfactory way for the fractionation of isotopes. A study of the vapor pressures of the hydrogen and deuterium oxides shows that there is a marked difference of vapor pressure even at the critical temperature of water, i.e., as the temperature increases, differences in vapor pressures do not necessarily at once become small. The same may be true in the case of the ammonias, and the question deserves further study to determine whether a fractionation column at ordinary temperatures, operating under pressure, might not produce a considerable fractionation of the nitrogen isotopes. A similar behavior might be observed in other cases, but as yet our knowledge of this subject is incomplete.

CHEMICAL EXCHANGE REACTIONS

The discovery of the isotope of hydrogen and the very extensive studies that have been made of the differences in chemical properties

of hydrogen, deuterium, and their compounds show that the chemical properties of isotopic compounds are not identical, and that slight but definite differences may be expected. The first calculation of such differences in chemical properties, made by Urey and Rittenberg[15] on the hydrogen-hydrogen iodide exchange reaction, showed again that marked differences could be expected. Subsequent calculations and experiments by many workers show that even larger differences in the chemical properties are present in many other cases, as, for example, in the exchange reaction between hydrogen and water. This work naturally led to a calculation of the equilibrium constants for exchange reactions involving other isotopes. The results of such calculations are given in Table 3. These calculations are from Urey and Greiff[8]

TABLE 3.—EQUILIBRIUM CONSTANTS OF GASEOUS EXCHANGE REACTIONS

Reaction	Equilibrium constant (α) 298.1 °K
$\frac{1}{2}SO_2^{16} + H_2O^{18} = \frac{1}{2}SO_2^{18} + H_2O^{16}$	1.028
$\frac{1}{2}CO_2^{16} + H_2O^{18} = \frac{1}{2}CO_2^{18} + H_2O^{16}$	1.054
$\frac{1}{2}O_2^{16} + H_2O^{18} = \frac{1}{2}O_2^{18} + H_2O^{16}$	1.020
$C^{12}O + C^{13}O_2 = C^{13}O + C^{12}O_2$	1.086
$\frac{1}{2}Cl_2^{35} + HCl^{37} = \frac{1}{2}Cl_2^{37} + HCl^{35}$	1.003
$\frac{1}{2}Br_2^{79} + HBr^{81} = \frac{1}{2}Br_2^{81} + HBr^{79}$	1.0004
$\frac{1}{2}N_2^{14} + N^{15}O = \frac{1}{2}N_2^{15} + N^{14}O$	1.015
$Li^6H + Li^7 = Li^7H + Li^6$	1.025
$Cl^{35}O_2 + \frac{1}{2}Cl_2^{37} = Cl^{37}O_2 + \frac{1}{2}Cl_2^{35}$	1.023
$Cl^{35}O_2 + HCl^{37} = Cl^{37}O_2 + HCl^{35}$	1.027

with the exception of the last two equilibria recorded, which were made by Dwayne T. Vier. These fractionation factors, α, deviate from unity by as much as 9 per cent in one case. The table shows that somewhat larger deviations from unity are obtained in the case of elements of low atomic weight than in the case of those of high atomic weight, but that even for elements as heavy as chlorine, a considerable fractionation may be expected. The calculations given in these tables are made by the use of well-established statistical mechanical theory, using experimental molecular spectra data for abundant molecules. The necessary vibration frequencies and moments of inertia for the rarer molecules are calculated by the use of the theory of small vibrations applied to molecules of this kind.

Exchange reactions involving two phases must be considered if countercurrent methods similar to distillation, using a fractionation column, are to be used. In the case of the liquid-gas phase equilibria the examples listed in Table 4 may be considered. The calculated val-

[15] UREY, H. C., and RITTENBERG, D. Journ. Chem. Phys. 1: 137. 1933; 2: 106. 1934.

TABLE 4.—EQUILIBRIUM CONSTANTS OF TWO PHASE EXCHANGE REACTIONS

Reaction	Equilibrium constant calculated	Equilibrium constant observed
$N^{15}H_3(g) + N^{14}H_4^+(aq) = N^{14}H_3(g) + N^{15}H_4^+(aq)$.	1.033	1.023
$HC^{13}N(g) + C^{12}N^-(aq) = HC^{12}N(g) + C^{13}N^-(aq)$.	1.026	1.013
$HCN^{14}(g) + CN^{15-}(aq) = HCN^{15}(g) + CN^{14-}(aq)$.	1.003	Slightly less than 1
$S^{34}O_2(g) + HS^{32}O_3^-(aq) = S^{32}O_2(g) + HS^{34}O_3^-(aq)$.	—	>1

ues of the equilibrium constants, which are also the values of the fractionation factors, α, have been secured by assuming that the distribution functions for the ions in solution are the same as those to be expected for a gas. Such calculations can not be exact, but experiment does show rather good agreement with the calculated values recorded in the second column of the table. The observed values depend upon our experiments made on the separation of the isotopes of carbon, nitrogen, and sulphur, and depend upon the rate of production of the heavy isotopes, assuming that equation (4) applies. Since our separation apparatus is run under conditions where this formula may give too low a value for the fractionation factor, and since experiments of this kind never run perfectly, the observed constants as given deviate less from unity than actually is the case. This is due to the fact that the transport is proportional to the deviation from unity of this constant, and any interruption of the process is likely to decrease the yield, and can not increase the yield under any circumstances. The table shows that the values calculated in this way are at least a good approximation to the experimental values.

Exchange reactions involving two liquid phases have been used by Lewis and MacDonald[16] to secure a partial separation of the lithium isotopes. The exchange reaction involved is given as the first reaction in Table 5. Exchange reactions between solid and liquid phase systems are illustrated by the last three equations of Table 5. In these cases it is impossible to make satisfactory calculations of the equilibrium constants, and only the constant observed by Taylor and Urey[17] in one case, namely, the lithium ion-lithium zeolite exchange reaction is recorded. In the potassium ion-potassium zeolite and the ammonium ion-ammonium zeolite reactions, only the direction of the deviation of the constant from unity can be given, and it seems difficult to deduce from the results of Lewis and MacDonald any value for the equilibrium constant for their exchange reaction.

[16] LEWIS, G. N., and MACDONALD, R. T. Journ. Amer. Chem. Soc. 58: 2519. 1936.

[17] TAYLOR, T. I., and UREY, H. C. Journ. Chem. Phys. 6: 429. 1938.

TABLE 5.—EQUILIBRIUM CONSTANTS OF ZEOLITE EXCHANGE REACTIONS

Reaction[1]	Equilibrium constant observed
Li^7 (amalgam) $+ Li^{6+} = Li^6$ (amalgam) $+ Li^{7+}$	>1
$Li^{6+} + Li^7Z = Li^{7+} + Li^6Z$	1.022
$K^{39+} + K^{41}Z = K^{41+} + K^{39}Z$	<1
$N^{14}H_4^+ + N^{15}H_4Z = N^{15}H_4^+ + N^{14}H_4Z$	<1

[1] The zeolite radical is indicated by the symbol Z.

Such two phase exchange reactions can be used for the separation of isotopes, and the effect of the simple process fractionation in the case of gas-liquid equilibria can be multiplied many times by the use of countercurrent apparatus of the distillation column type. In the case of liquid-liquid equilibria, countercurrent liquid flow can be used in a similar way, but in the case of the liquid-solid equilibria, a countercurrent flow of this kind would be very difficult to maintain. In this latter case, procedures similar to those of chromatographic analysis can be used effectively.

The apparatus which has been used by my colleagues and myself for the fractionation of the nitrogen, carbon, and sulphur isotopes consists of the packed column type of fractionation column. The time which is required for such apparatus to come to a steady state may be very long indeed, and in the experiments which we have conducted years would have been required in some cases if special types of operation had not been employed. The transport of the column is given approximately by equation (4), and this shows that the transport is proportional to the total flow in the column and to the concentration of the less abundant material, provided that the mole fraction of this less abundant material is small. Thus if one fractionation column will increase the concentration by some factor, F, the total flow could be decreased in the next column by the same amount and still the transport would remain the same. Therefore a second column is made to operate on the product of the first, the second column having a smaller total flow and a smaller hold up, and hence the final steady state is reached in a much shorter time than if this additional fractionation had been carried out with the column of the same size as the first one. In this way the steady state is reached much more quickly, with the same transport. A third still smaller column can now be used to operate on the product of the second in a similar way.

Fig. 1 shows diagrammatically the arrangement of the apparatus which we have used for the concentration of the nitrogen isotopes.[18] In this case the heavy isotope concentrates in the liquid phase. An

[18] THODE, H. G., and UREY, H. C. Journ. Chem. Phys. 7: 34. 1939.

ammonium-nitrate solution containing 60 per cent by weight of the salt was pumped into the top of the first unit. This unit increased the concentration of N^{15} by a factor of about 7. Six-sevenths of the material was withdrawn at the bottom, sodium hydroxide added, and the ammonia removed from the solution by boiling and passed back upward through this unit. One-seventh of the material flowed to Unit 2, which changed the concentration of the nitrogen isotopes by an additional factor of 9. About eight-ninths of the material was removed

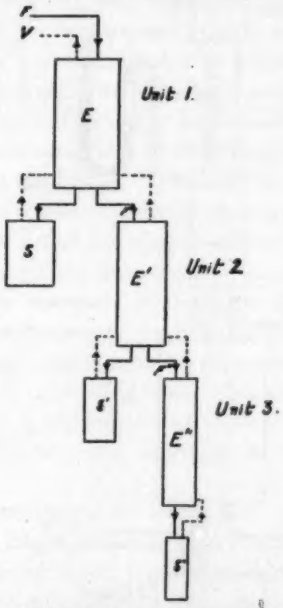

Fig. 1.—Arrangement of fractionation units (E, E', E'') in nitrogen apparatus. Stripping units are indicated by S, S' and S'', liquid flow by solid lines (F), and gas flow by broken lines (V).

at the bottom of this column, sodium hydroxide added, and the ammonia sent upward through the unit, while one-ninth went to Unit 3, which further changed the ratio of the nitrogen isotopes by a factor of 11. The ammonia was finally liberated at the bottom, passed upward through all the units, as indicated by the arrows, and finally absorbed in water at the top of Unit 1. The arrangement is similar to a distillation apparatus except that a large reservoir of material is maintained at the top of the first unit and total reflux at the bottom. The solution takes the place of the liquid in a distillation apparatus, and the ammonia gas replaces the vapor in distillation. Rapid exchange takes

place between the ammonium ion and ammonia just as equilibrium is maintained between the liquid and the gas in a distillation.

The arrangement used in the carbon case[19] is illustrated in Fig. 2. Only two units were used since we make use of hydrogen cyanide and not too large quantities could be used in a laboratory building. In this case, C^{13} concentrates in the gas phase and therefore the general ar-

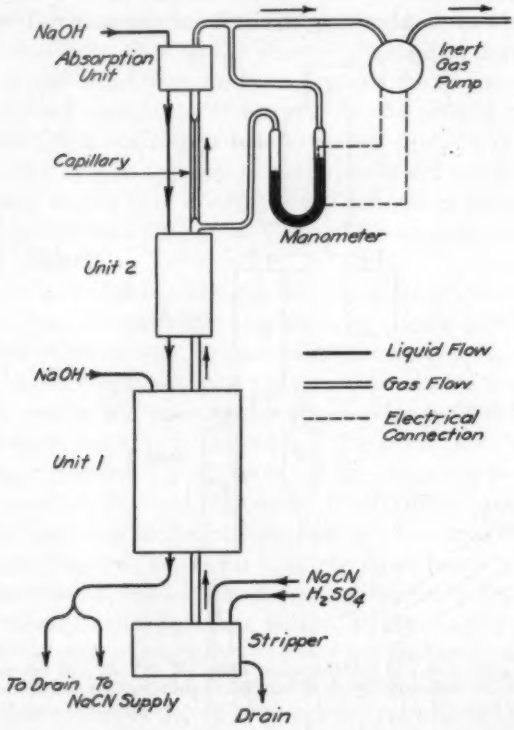

Fig. 2.—Arrangement of fractionation units in the carbon apparatus.

rangements must be inverted as compared with the nitrogen separation. Solutions of sodium cyanide and sulphuric acid are pumped into the bottom of Unit 1 and the hydrogen cyanide removed from the solution by a stripping column. Hydrogen cyanide gas rises through Unit 1. At the top, sufficient sodium hydroxide (free of iron) is added to absorb about four-fifths of the hydrogen cyanide. This unit changes the ratio of the carbon isotopes by a factor of about 5. The remainder

[19] HUTCHISON, C. A., STEWART, D. W., and UREY, H. C. Journ. Chem. Phys. In press.

of the hydrogen cyanide gas passes to the bottom of Unit 2, and at the top of Unit 2 sufficient sodium hydroxide is added to absorb it. This second unit changes the ratio of the carbon isotopes by approximately a factor of 6.

Small amounts of air are introduced into the apparatus with the solutions, and if these are not removed from the top of the second unit the air will accumulate there and prevent the hydrogen cyanide from reaching the top of this unit. As time went on the apparatus would completely fill with air, and no fractionation would be obtained since all absorption of the hydrogen cyanide would occur at the bottom of the first unit. To avoid this it is necessary to remove the inert gas at the top of the second unit. This is done by connecting an additional absorbing unit with the top of Unit 2 by a capillary tube. The sodium hydroxide is pumped first to the absorbing unit and from the bottom of this to the top of Unit 2. Part of the HCN is neutralized in the absorbing unit and the remainder at the top of Unit 2. As the inert gas accumulates at the top of the absorbing unit, the flow of hydrogen cyanide through the capillary decreases. A manometer arranged with an electrical contact is attached to the ends of the capillary so that the pressure difference measures the rate of flow of HCN. When the pressure difference falls to zero, a pump is started which removes inert gas from the top of the absorbing unit. This causes rapid absorption of HCN in the absorbing unit again, and the pressure drop across the capillary is restored. In this way inert gas is removed automatically without difficulty.

The apparatus is controlled by fixing the rates with which alkali enters the tops of the two units. The rate of supply of hydrogen cyanide at the bottom is regulated by maintaining a constant pressure at this point through a manometer with an electrical contact which starts and stops the feed pump.

The actual form of the apparatus is illustrated in Fig. 3 for the case of the nitrogen separation. Only the two smaller units are used for the carbon separation. A detailed description of this apparatus has been published elsewhere.[18]

Taylor and Urey[17] have made use of the liquid-solid equilibria to effect a change in the ratio of the lithium, potassium, and nitrogen isotopes. In these cases a 30-foot tube was filled with a zeolite, say, for example, a sodium zeolite and covered with a solution of sodium chloride. Lithium chloride solution was then fed into the top of the tube and the solution withdrawn at the bottom. Since lithium 6 is concentrated in the zeolite rather than in the lithium chloride solution, it is

retarded relative to lithium 7 in its movement down the column. After some time the solution leaving the bottom of the column will contain lithium ion and this will be enriched in lithium 7; that is, the leading sample contains the heavier lithium. One can then wash out the lith-

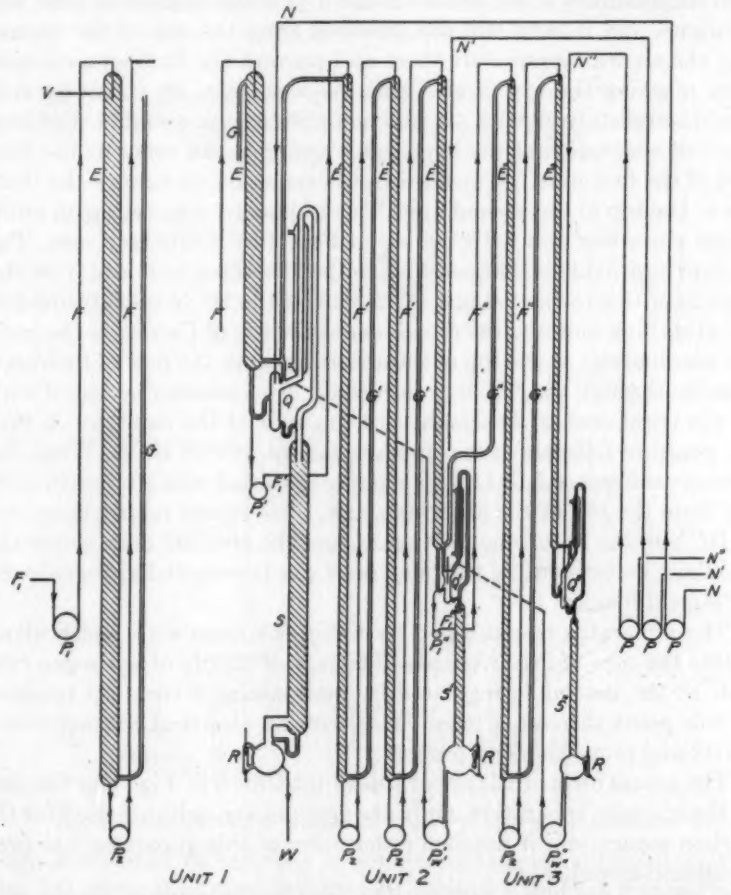

Fig. 3.—Complete apparatus as used in the separation of the nitrogen isotopes.

ium chloride from the zeolite and in this case the trailing sample is enriched in lithium 6. Fig. 4 represents results secured in such experiments by Taylor. A rather marked change in the relative abundance of lithium is secured by this simple method. Similar experiments using potassium and ammonium salts showed that changes in the relative

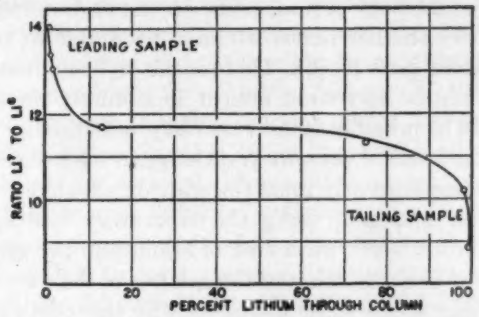

Fig. 4.—Distribution of lithium isotopes coming through a zeolite column.

abundances of the isotopes of potassium and nitrogen result from such experiments, but that the heavier isotopes are concentrated in the trailing samples in these cases.

CRITIQUE OF SEPARATION METHODS

In considering the relative advantages of various methods for the separation of isotopes, several factors must be kept in mind. In the first place there is the question of the amounts of isotopic materials that are required for experiments. For effective work most chemical experiments require amounts of the order of grams of these separated isotopes. In the second place, the cost of production is an important item. If one is separating only small amounts as a laboratory curiosity or for a very few special problems, then the cost becomes relatively unimportant. However, if one looks upon separated isotopes as a new tool for chemical research in all its various aspects, then the matter of production cost on a commercial basis is important. The value of such stable isotopes as tracers, as compared with the value of radioactive isotopes, depends upon the amount by which the material can be diluted before the tracer can no longer be detected, upon the size of sample that is required for analysis, and upon the convenience of the analytical method. It is very difficult for me to speak authoritatively in regard to other methods of separation than these chemical ones, but in the case of the chemical method it is of interest to record some facts in regard to the cost, and the usefulness of the separated isotopes particularly for tracer use.

The rate of production by chemical methods, using apparatus of the type I have described, is considerably larger than that of any other type of separation that has been used, so far as I am aware. In the case of our nitrogen experiments, it was possible to transport 0.75

gram of N^{15} per 24-hour period, while on the carbon experiment (using only the two smaller units) we have been able to transport 0.15 gram of C^{13} per 24-hour period. There seems to be no reason why these methods can not be increased almost indefinitely on a commercial scale. It should be possible to increase the production by at least a factor of 10 on the basis of present knowledge in both cases. The cost of production depends greatly upon the scale on which one works. In our experiments on nitrogen, using the laboratory size apparatus, we were able to produce N^{15} for a cost of about $50 per gram of N^{15}, including the cost of chemicals and the salaries of the men operating the apparatus. There seems to be no reason why this cost can not be lowered to something in the neighborhood of $15 per gram of N^{15}, or less. In the case of carbon, our cost for salaries and chemicals amounts to about $200 per gram, although there appears to be no reason why this cost can not also be brought to the neighborhood of $15 or $20 per gram if the production is maintained on a sufficiently large scale.

These figures, of course, can not be regarded as total costs for the reason that in any commercial venture it is necessary to charge overhead, which is an important part of the cost of production, but it does seem probable that these isotopes can be produced and sold for something in the neighborhood of $50 per gram.

The dilution factor of the material we are now producing, 25 percent C^{13}, is approximately 2500 to 1, if we assume that the precision of a mass spectrometer is limited to 1 percent of the natural abundance of C^{13}. If mass spectrometers can be devised which are able to detect 0.1 percent of the natural abundance of C^{13}, and this does not seem impossible, the dilution factor for our present material is 25,000.

The sample required for satisfactory analysis with a mass spectrometer is in the neighborhood of 1 cc of gas at atmospheric pressure, and if necessary this could quite easily be reduced to one-fifth of this, or approximately 0.1 milligram of C^{13}. The method of analysis requires a rather extensive and somewhat expensive piece of apparatus, and one that at the present time is often difficult to keep in satisfactory adjustment. There appears to be no reason, however, why such an apparatus can not be made commercially in a much more convenient form than those now in use in our laboratories, and at a cost comparable to medium sized spectrographs.

Distillation, chemical exchange reactions, thermal diffusion, and centrifugal evaporation all depend upon the possibility of using volatile compounds. The relative advantages of the thermal diffusion and the chemical methods can be rather well evaluated at the present

time. The chemical methods rapidly become ineffective as atomic weights increase. For example, it would appear that fractionation factors in the neighborhood of 1.0002 might be expected in the case of elements of atomic weight 200 or more, instead of 1.02 as in the case of carbon and nitrogen. It is thus evident that it will probably be impossible to effect any separation of isotopes on an effective scale by chemical methods for elements above 40 in atomic weight. On the other hand, the thermal diffusion coefficient can be expected to be about 0.1 as great for elements of atomic weight 200 or more, as for carbon. Thus we see that its use over a wider range of the periodic system is possible, although the speed of the method per unit apparatus is only about 5 or 10 milligrams of C^{13} per 24-hour period. To attain a production of 1 gram of C^{13} per 24 hours would require at least 100 thermal diffusion tubes, while the chemical separation can be effected on the same scale with a single apparatus of somewhat more extensive character than those already used. While the thermal diffusion method can be easily operated without attention, chemical methods require constant attendance. The comparison for a case such as carbon comes to a matter of cost of production. Electrical current is particularly expensive for the thermal diffusion method, probably running in the neighborhood of $100 per gram of C^{13} transported. Other methods of heating can hardly be expected to have the uniformity and the steady character required for the efficient operation of the process. It seems quite certain that the construction and operation of 100 thermal diffusion tubes can not be expected to be as economical as the operation of a single chemical separation apparatus, even though the chemical method must have constant attention. Moreover, if larger amounts are needed the chemical method can be extended to larger scale apparatus by methods that are well understood in the chemical industry.

Turning to the possible separation of the elements of high atomic weight, we see that the centrifugal fractionation column is the most feasible method. It should have a transport per unit comparable to chemical exchange units of approximately the same size. Moreover, the effectiveness of separation should decrease very slowly with increased atomic weight, the decrease being due to slower rates of diffusion in the case of high atomic weight substances, and not due to a decrease in the effective fractionation factor.

It is always interesting to speculate on where the next important development of a subject will take place. At the present time the separation of the uranium isotopes would probably lead to most in-

teresting progress in the study of the fission process of the uranium isotope of mass 235. Thermal diffusion seems to be a possible method for accomplishing this, although no very great speed can be expected. It would seem to me that the centrifugal fractionation column or some modification of this would be a most likely method for securing results on this most fascinating problem, and in my opinion this is the most important direction for research on the concentration of isotopes at the present time.

I have been greatly aided in the work that I have reported in this lecture by my colleagues who have worked with me for various periods of time since this work was started about five years ago. Prof. John R. Huffman, now at New York University, aided with the distillation experiments on the O^{16} and O^{18} waters and with the early experiments on the separation of the nitrogen isotopes. Prof. Harry G. Thode, now at McMasters University, did much of the work on the final separation of the nitrogen isotopes and aided with the first experiments on C^{13}. Prof. Clyde A. Hutchinson, now at the University of Buffalo, Dr. Irving Roberts, of Weiss & Downs, Inc., and Dr. David W. Stewart, of Columbia University, are in a large measure responsible for the success of the separation of carbon. Dr. Karl Cohen has helped with the more recent experiments and has carried through the calculations on the fractionation process reported in this paper. From time to time other men have aided us with the actual mechanical work of carrying on these rather arduous experiments. My thanks and appreciation are due to all these men, for the program could not have been performed without the loyal help of my co-workers.

BOTANY.—*Aublet the botanist, a pioneer against slavery, with a memorial genus of palms.*[1] O. F. Cook, Lanham, Md.

Darwin's reaction against slavery, during his visit to Brazil in 1832, has figured as an example of humanitarian sentiments combined with scientific pursuits, to show that science is not so aloof from human interests as often supposed. Cuvier affirmed "the power of feeling to exalt the intelligence," but curiosity affects the mysterious and remote. Darwin noted in Galton's questionnaire on heredity that more originality is implied in "discoveries with regard to common objects," and Aublet saw significance in simple racial reactions that continued to be disregarded through the slavery controversy. From a scientific standpoint it must be expected that the racial and social problems,

[1] Received December 22, 1939.

since they lie in the field of biology, eventually will be studied by consecutive scientific methods, and that each discovery or original approach to a significant fact will be recognized, appreciated, and commemorated.

Aublet not only was much earlier than Darwin but was well in advance of most of the philanthropists who gained distinction through their efforts for the suppression of the slave trade and the abolition of slavery, as Sharp, Wilberforce, Buxton, Garrison, and Phillips. Abbé Gregoire did not organize his "Friends of the Blacks" till 1788, the same year when Brissot de Warville traveled in the United States with a zealous interest in the "wretched Africans." Clarkson's survey of his "forerunners," in *The history of the abolition of the slave trade*, 1808, does not refer to Aublet, nor does Saco's *Historia de la esclavitud*, 1879–1903.

Jean Baptiste Christophe Fusee Aublet, a contemporary of the Jussieus, was born in Provence in 1720, and is chiefly known for his *Histoire des plantes de la Guiane Françoise*, 1775, in four octavo volumes, the foundation of forest botany in tropical America. Nearly 400 new plants were described and figured, including many new genera of trees. Piso, Plumier, Browne, Sloane, and Jacquin had explored the plant world of the West Indies and the shores of South America, but Aublet entered the continental forest and began the study of its seemingly inexhaustible flora, continued by Ruiz and Pavon, Martius, Spruce, Pittier, and many others. Aublet was bent on botany even as a boy, ran away to Spain in search of plants, and worked a year for an apothecary at Granada before he was traced and taken home.

The Guiana collection was made in two years, 1762–1764, but Aublet had spent 9 years, 1753–1761, in establishing a garden of drug plants in Mauritius, then a French colony, "l'Isle-de-France." In returning from Guiana he spent several months in "Saint-Domingue," at Mole Saint Nichols, Bombardopolis, and other points in the northern peninsula of Haiti. Thus Aublet had active experience in three of the tropical colonies as a basis of his chapter on "Observations sur les Negres Esclaves," published in the supplement of the *Histoire*.

Slavery had been challenged on grounds of religious sensibility from the time of Las Casas in the sixteenth century, more frequently after George Fox visited Barbados in 1671 and urged a gradual emancipation of the slaves, as did John Woolman in Maryland and Virginia before the Revolutionary War. Aublet was a secular voice, perhaps the first to be raised, objecting to the system of slavery as injurious to the European settlers. He saw that the French colonists, from being

kindly, good-natured people, became haughty, hard, and inhuman in dealing with another race, but saw no object in this severity, the Negroes being, in his view, not turbulent savages, but naturally quiet, peaceable people, not entirely irresponsible or unwilling to work for what they might need.

Thus Aublet reached the conclusion that holding the Negroes in slavery was not necessary for maintaining the colonies, a racial judgment that received a practical demonstration in hundreds of separate communities on tropical coasts and islands when the system of forced labor eventually was abandoned. Much of the calamitous history of Haiti and of the United States might have been avoided if Aublet's factual view of the Negro character had prevailed before the explosive tensions were generated. It generally was believed that continuous repression was required and that the Negroes would revolt at the first opportunity. John Brown had that idea, and many other abolitionists.

In the light of subsequent history it will not be questioned that the effect of slavery on the ruling class was a serious factor of the racial problem of the West Indies. From Bolingbroke's *Voyage to the Demerary*, 1807, it appears that many of the islands were going backward long before the slaves were liberated. Emancipation did not change the essential conditions, and the decline continued. "A ruling class always rules itself out." Some of the finest islands have been entirely abandoned to the Negroes, and now this "New Africa" is reported in serious distress. Macmillan's *Warning from the West Indies*, 1936, urges an extension of the policy of trusteeship, "development in the interest of the weaker classes," as projected for the African colonies. The notion of ruling another race takes another form, benevolent, of course, but requiring "a firm exercise of authority in their behalf." In South Africa it is being recognized that the exploitive relations are detrimental to both races, and measures of segregation are being applied.

A few years after Aublet an English botanist, Henry Smeathman, outlined a plan for settling colonies of civilized Negroes on the coast of Africa, in order to end the slave trade and eventually to return the slave population from America. Smeathman went to Sierra Leone in 1771 to collect plants for a scientific group of English Quakers described by R. Hingston Fox in *Dr. John Fothergill and his friends*, 1919. An African tree of the passion-flower family was named *Smeathmania* by Robert Brown, in Tuckey's Congo *Narrative*, 1818. Two of Smeathman's letters, dated 1783 and 1786, relating to a proposed

settlement at Sierra Leone were included in Wadstrom's *Essay on colonization*, 1794. Smeathman's account of the social economy of the African termites, published by the Royal Society in 1781, is praised in Maeterlinck's *Life of the white ant* as an "inexhaustible treasure" of basic observations.

The policy of colonization had the approval of Washington and Jefferson, and settlements in Liberia were developed by Ashmun (1822–1828) to the point of showing that the project was feasible, though later mismanaged and discredited, but still finding a few supporters in each generation. Senator Bilbo of Mississippi recently has proposed in Congress a "Greater Liberia Act," for resuming and extending "the voluntary resettlement of American Negroes in Africa." A century of peaceable history in Liberia confirms Aublet's assay of the racial temperament.

A GUIANA PALM GENUS TO COMMEMORATE AUBLET

The palm called "maripa" in French Guiana, figured on the frontispiece of Aublet's *Histoire* and described in the Supplement, is distinct as a genus from the South American palms with which it has been associated and may receive the name **Ethnora,** to symbolize the interest of Aublet in the racial problems. The name *Attalea maripa* was given to Aublet's palm by Martius, and Drude called it *Maximiliana maripa*. The type species would appear as *Ethnora maripa* (Martius). The ample duplex perianth, uniform, crassate endocarp, and superficial submedial foramina, are diagnostic characters. The pulp of the fruit yields an edible oil. The related genera were reviewed in the National Horticultural Magazine for October 1939, in a paper entitled "*Bornoa*, an Endemic Palm of Haiti."

Other distinctive features of *Ethnora* are the low, robust trunk, rather short leaves, and the pedunculate inflorescence, less compact than in *Bornoa*. The large orbicular-apiculate petals are half as long as the fruit, twice as long as the broadly cordate-auriculate sepals, and about three times as long as the tomentose laciniate staminal cup. The stigma is persistent, the rostrum indurated, the exocarp firm, the mesocarp fleshy and fibrous with a compact inner layer of longitudinal mesocarp fibers adhering closely to the endocarp but not fused, the cross section showing only the few fibers that outline the sutural sclerites. One or two carpels are fertile, the endosperm narrowly striate on the outer face, and the slender curved embryo protected by a papilliform process of the indurated testa. Fruits from Dutch Guiana collected by Harold F. Loomis for the Allison V. Armour Expedition of 1932 have been examined.

The endocarp of *Ethnora* is remarkable, the walls very thick and extremely hard, of uniform texture, with no peripheral fibers, but the sutural sclerites distinctly outlined in the cross section of the nut by parallel series of fibers, rather regularly spaced. In *Bornoa* the sutural bands appear as segments of the outer wall separated by a few fibers in radial or oblique rows, but in *Ethnora* it is plain that the bands project as radial flanges from the center of the nut and are structurally distinct from the thickened walls of the carpels, which doubtless must be considered as the endocarp proper. The central structure is hardly to be viewed as a receptacle or a placenta but

Palmier maripa.
Regime de maripa, et Fruit détaché.
Palmier caraou.
4. Grappe du regime de caraou.
5. Grappe du regime d'avoira.
6. Fruit du Palmier hache détaché.
7. Regime du Palmier aquiniete.
8. Cocos triangulaire.
9. Cocos ovoyene.

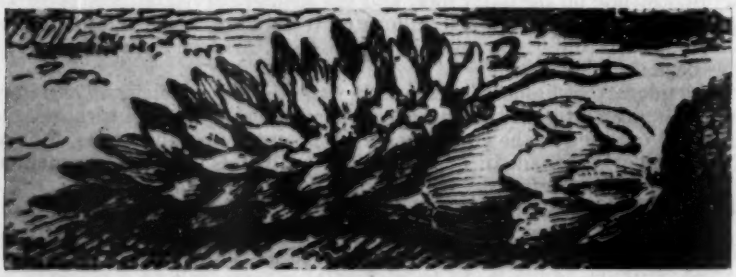

Fig. 1.—Aublet's maripa palm.

may represent an intermediate metamere, between the stamens and the pistils. The nut of *Temenia* (*Maximiliana*) shows the same structure as *Ethnora*, but the walls are much thinner, with the pits that mark the sutural bands more numerous, closer to the surface of the chambers, and distinctly flattened.

The personal name *Aubletia* is not available, Gaertner in 1788 and four other botanists within a few years having dedicated new genera to Aublet. Only the first genus could be recognized, and that proved invalid.

A reduced photograph of Aublet's frontispiece is reproduced (Fig. 1), with an enlargement of the details of the maripa palm. The four other palms "comon," "avoira," "bache," and "zaguenete" are identified respectively as *Oenocarpus*, *Astrocaryum*, *Mauritia*, and *Manicaria*. No other palms were illustrated in Aublet's *Histoire*, though several were briefly described, without botanical names. The leaf above the medallion may represent the "comon."

The palm of Dutch Guiana may be a different species, since it develops a tall, clean, cylindrical trunk. A single fruit of this palm is 7 cm by nearly 4 cm, the petals attaining 4 cm and the sepals 2 cm. An inflorescence branch with 6 fruits is 18 cm long, the basal joint nearly 4 cm the other joints about 2 cm, and the slender male section 4 cm.

The name "cocorite" or "kokerite" also is applied to palms of this group in Guiana and Trinidad, usually classified under *Maximiliana*.

In British Guiana, according to Im Thurn, the cocorite palms are short or even stemless in the coast districts, but in the interior grow very tall, "the grandest column-like stem that palm ever had." The name "mareepa" is given by Im Thurn as relating to the seeds of the cocorite palm.

From Aublet's descriptions a genus *Avoira*, with six formally named species, was recognized by Giseke in 1792, though generally overlooked in taxonomic literature. Giseke's genus antedates *Astrocaryum* Mayer, 1818, but may prove distinct. The type species, *Avoira vulgaris*, is represented in Aublet's drawing by a branch of the inflorescence with several fruits, while a branch of *Astrocaryum aculeatum* Mayer appears from the original description to have only one female flower, at the base of a slender "stipe" equal in length to the thickened male spike.

BOTANY.—*A second note on Georgia Discomycetes.*[1] EDITH K. CASH, U. S. Bureau of Plant Industry. (Communicated by JOHN A. STEVENSON.)

During the past few years the writer has had the privilege of studying numerous specimens of Discomycetes collected in the vicinity of Athens, Ga., by J. H. Miller and G. E. Thompson, of the University of Georgia. Several of these fungi have been discussed previously (2); notes are given here on five additional species, four of which are described as new. Specimens are in the herbarium of the University of Georgia and in the Mycological Collections of the U. S. Bureau of Plant Industry, and type material has also been deposited in the Farlow Herbarium of Harvard University and the herbaria of the New York Botanical Garden and the University of Michigan.

[1] Received January 2, 1940.

Sphaeropezia arundinariae, n. sp. Fig. 1

Apothecia irregularly scattered over the stems of the host plant, ellipsoid or elongate, 0.7–1 by 0.3–0.5 mm, deeply embedded in the tissue, at first completely covered by a lid concrete with the darkened and convexly arched epidermis, which later splits longitudinally to expose the sunken hymenium; hymenium pale flesh color to vinaceous-buff (Ridgway),[2] pruinose; asci cylindrical, rather abruptly narrowed to the apical pore, gradually attenuated toward the base, pore blue with iodine, 8-spored, 75–85 by 6–8μ; spores irregularly biseriate, hyaline, cylindrical-clavate, 3-septate, not constricted, rounded at the ends and narrowed at the lower end, 16–18 by 3–4μ; paraphyses hyaline, filiform, simple or branched near the tips, often twisted or circinate; hypothecium hyaline or subhyaline, of small-celled plectenchyma; exciple prosenchymatous, brown, enclosing the hymenial layer at the base and sides and the cover above it in a continuous layer; cover concrete with the epidermis, the outer layer prosenchymatous, brown, with a thick inner layer of hyaline, gelatinous longitudinal cells, opening by a lengthwise slit, the sections extending perpendicularly or more frequently breaking away at maturity and leaving only a few fragments around the margin of the hymenium.

Apotheciis conspersis, ellipsoideis vel elongatis, 0.7–1×0.3–0.5 mm, immersis, clypeo epidermide adnato et longitudinaliter fisso et hymenium pallide-roseum pulverulentum patefacienti; ascis cylindricis, octosporis, 75–85 ×6–8μ; ascosporis biseriatis, hyalinis, cylindrico-clavatis, 3-septatis, base attenuatis, 16–18×3–4μ; paraphysibus hyalinis, filiformibus, simplicibus vel apice ramosis, saepe circinatis, hypothecio subhyalino, plectenchymatico; excipulo prosenchymatico, brunneo.

On the small branches of *Arundinaria tecta*, Bobbin Mill, Athens, Ga., April 27, 1938, J. H. Miller, and April 5, 1939, G. E. Thompson and J. H. Miller (*type*).

This fungus was at first tentatively placed in the genus *Phragmonaevia*, which it resembles in its sunken apothecia and hyaline, septate spores. The inadequate descriptions of many species of this genus make their real characters and affinities questionable. Details of the structure and development, particularly the manner of opening and the nature of the covering layer, if present, are usually not noted. Although von Hoehnel in several instances (4, 5, 6) notes the resemblance of some species of *Naevia* to *Phacidium*, at one time classifying the genus *Naevia* in the Phacidiaceae, he consistently regarded *Phragmonaevia* as belonging to the Stictidaceae, as have Saccardo and Rehm, among other writers. The fungus on *Arundinaria*, however, can not be considered as stictidaceous, being plainly most closely allied to the Phacidiaceae. The structure of the apothecium is strikingly similar to that of *Phacidium lacerum* Fr., the type of the genus *Phacidium*, as illustrated and described by von Hoehnel (4, p. 317, fig. 15). Von Hoehnel's figure shows a similar covering lid, open and extending vertically at right angles to the hymenium, with an inner layer of mucilaginous cells, which he interprets as an opening mechanism.

[2] Color terminology follows Ridgway, *Color standards and color nomenclature*, Washington, D. C., 1912.

Several species of *Phragmonaevia* growing on grasses are transferred by von Hoehnel and Nannfeldt to *Hysteropezizella* v. Hoehn., a genus characterized by elongate ascomata, a covering lid concrete with the epidermis and opening at one side, simple spores, and acute lanceolate paraphyses. *S. arundinariae* differs from *Hysteropezizella* in the filiform, flexuous paraphyses, septate spores, and most especially in the prosenchymatous exciple. No pseudoparenchymatous basal tissue, such as that illustrated and described by von Hoehnel and Nannfeldt, could be found in this fungus.

The original description of *Sphaeropezia* Sacc. (10, p. 253) is brief, and the type species, *S. alpina* Sacc., appears not to have been available for study by later workers, so that the position of the genus is not clear. First described as a genus of the Patellariaceae by Saccardo, it was referred by Rehm (9, p. 72–73) to the Phacidiaceae, a classification that was adopted by Saccardo in the *Sylloge Fungorum*, volumes 8–24, and followed by von Hoehnel (5). Nannfeldt (8, p. 214), on the other hand, on the basis of his examination of *S. empetri* (Fckl.) Rehm, considers *Sphaeropezia* a member of the Pseudosphaeriales, removing it from the Discomycetes completely, but not assigning it definitely to any family. In the absence of more adequate information, the writer has followed the usage of Rehm and von Hoehnel in describing this fungus as a *Sphaeropezia*.

Lachnum arundinariae, n. sp. Fig. 2

Apothecia sessile, scattered, amphigenous, mostly hypophyllous, superficial, minute, 0.1–0.2 mm in diameter, translucent when moist, white-pilose, subglobose then patellate, soft-fleshy, hymenium hyaline to sea-shell pink (R), margin fimbriate; asci cylindrical, short-pedicellate, rounded at the apex, 8-spored, 27–33 by 3–3.5μ; spores narrow-clavate to acicular, biseriate, unicellular, hyaline, straight, 5–6.5 by 0.7–1μ; paraphyses lanceolate, 45–55 by 3–4μ; exciple hyaline, prosenchymatous; hairs hyaline, septate, finely echinulate, not swollen at the apex, 50–70 by 3μ.

Apotheciis sessilibus, amphigenis, 0.1–0.2 mm, molle carnosis, albo-pilosis, margine fimbriato, hymenio carneo; ascis cylindricis, breve pedicellatis, octosporis, 27–33×3–3.5μ; ascosporis anguste clavatis vel acicularibus, unicellularibus, hyalinis, 5–6.5×0.7–1μ; paraphysibus lanceolatis, 45–55 ×3–4μ; excipulo hyalino, prosenchymatico; pilis hyalinis, septatis, echinulatis, 50–70×3μ.

On *Arundinaria tecta*, Bobbin Mill, Athens, Ga., April 27, 1938, J. H. Miller, and May 12, 1939, G. E. Thompson and J. H. Miller (*type*).

Judged from the description, *Peziza caulicola* Fr. (3, p. 94), reported on *Arundinaria*, is close to *Phialea cyathoidea*. Both the former species and *Peziza arundinariae* Berk. (1, p. 155) differ from *Lachnum arundinariae* in color and in the presence of a stipe. Among species of *Lachnum* that occur on grasses, *L. carneolum* (Sacc.) Rehm f. *hyalinum* (Rehm, Ascomyceten no. 1931) is more densely pilose, with thicker, longer, crystal-bearing hairs, larger asci and spores, and shorter paraphyses; *L. nardi* Rehm is a darker, stipitate species; and European specimens of *L. controversum* (Cke.) Rehm show larger, stouter apothecia, with clavate-tipped hairs and spores equally acute at both ends.

Pyrenopeziza minuta, n. sp. Fig. 3

Apothecia hypophyllous, subcuticular, becoming superficial with the disorganization of the host tissue, closely aggregated in pale spots of withering leaves, patellate, pale brown when moist with subhyaline hymenium, entire fungus black when dry, very inconspicuous, 150–175μ in diameter, soft fleshy to membranous, margin uneven; asci clavate to fusoid, rather abruptly narrowed at the apex and base, 8-spored, 28–33 by 4–5μ; spores biseriate or irregularly 3-seriate in the upper part of the ascus, acicular clavate, 4–5 by 0.7–1μ; paraphyses filiform, hyaline, swollen at the tips to 2–3μ in diameter and conglutinate in a yellowish mazaedium; hypothecium thin, subhyaline, outer layer dark at the base, of elongate, yellow-brown hyphae forming a dentate margin.

Apotheciis in maculis hypophyllis, subcuticularibus dein superficialibus, patellatis, pallide brunneis, 150–175μ diam., molle-carnosis vel membranosis; ascis clavati-fusoideis, octosporis, 28–33×4–5μ; ascosporis 2-3-seriatis, aciculari-clavatis, 4–5×0.7–1.2μ; paraphysibus filiformibus, hyalinis, apice inflatis et conglutinatis; hypothecio tenui, subhyalino; excipulo brunneo.

In withered leaves of *Tilia heterophylla* var. *michauxii*, Princeton, Ga., April 26, 1938, and March 25, 1939 (*type*), J. H. Miller and G. E. Thompson.

This species differs from *Naevia tiliae* (Kleb.) Nannf. (8, p. 190) in smaller asci and spores, longer paraphyses, and in the thinner, darker basal tissue.

Pyrenopeziza prinicola (E. & E.), comb. n.

Synonym.—Mollisia prinicola E. & E., Journ. Myc. **4**: 99. 1888.

Apothecia erumpent, then superficial, scattered rather thickly and evenly over the lower surface of the leaf, minute, 150–275μ in diameter, subturbinate then patellate, membranous to fleshy, hymenium alutaceous to dark brown, the entire fungus black when dry, margin slightly crenulate; asci clavate, abruptly narrowed at the base and apex, 8-spored, 33–40 by 6–8μ; spores irregularly 2–3-seriate, hyaline, acicular-clavate, 1-celled, guttulate, becoming pseudoseptate near the middle, the lower end acute and narrowed, straight, 10–15 by 1–1.5μ; paraphyses filiform, hyaline, simple or branched near the tips; hypothecial layer hyaline, plectenchymatic, 15–20μ thick, gradually changing to subhyaline pseudoparenchyma at the base; exciple subhyaline at the base, dark toward the margin, covered with brown hyphae 2–3μ in diameter adnate with remnants of the host cuticle.

On dead leaves on *Quercus stellata*, Bobbin Mill, Athens, Ga., April 27, 1938, J. H. Miller; on *Quercus rubra*, same locality, May 12, 1939, G. E. Thompson and J. H. Miller. Type on *Q. prinus*, Louisiana, 1888, A. B. Langlois 1329.

Comparison with the type specimen of *Mollisia prinicola* E. & E. in the Mycological Collections of the Bureau of Plant Industry shows that the Georgia material constitutes recent collections of the same species, which is, however, more properly a *Pyrenopeziza* than a *Mollisia*.

So far as can be ascertained from descriptions and available specimens this American fungus is not identical with similar European species occurring on oak leaves. *Mollisia rabenhorstii* (Auersw.) Rehm (9, p. 537) has smaller asci and spores, apothecia free from the host tissue at the border instead of

adnate with it, and a darker, large-celled pseudoparenchymatous exciple with conspicuous, broad, clavate ends of hyphae projecting at the margin. Rabh. F. Eur. 2312, issued as *Pyrenopeziza foliicola* Fckl. and cited by Rehm as *M. rabenhorstii*, agrees with Rehm's description of the latter species; Sacc. Myc. Ven. 975, labeled *Pyrenopeziza foliicola* (Karst.) Sacc. f. *quercus pedunculata*, and *Peziza nervicola* Desm. in Desm. Pl. Crypt. Fr. 1067 also appear to be the same fungus, differing from *P. prinicola* in the characters mentioned.

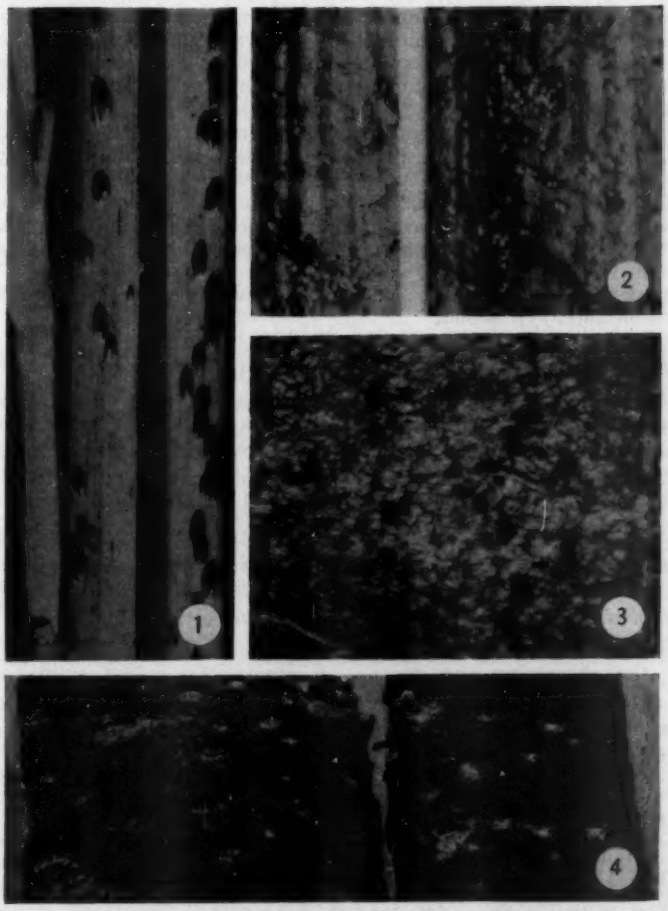

Fig. 1.—*Sphaeropezia arundinariae* on *Arundinaria tecta* (× 5). Fig. 2.—*Lachnum arundinariae* on *Arundinaria tecta* (× 20). Fig. 3.—*Pyrenopeziza tiliae* on *Tilia heterophylla* var. *michauxii* (× 18). Fig. 4.—*Phaeangium magnisporum* on *Betula nigra* (× 5). Photographs by M. L. F. Foubert.

Phaeangium magnisporum, n. sp. Fig. 4

Apothecia erumpent singly or in groups of two to three, closely surrounded by fragments of broken bark, 1–1.5 mm in diameter, fleshy, subturbinate or obconic, smooth, black, often compressed and contorted, readily falling out, leaving cavities in the bark, hymenium fuscous-black (R), shining, rough; asci broad-cylindrical, abruptly narrowed at the base, rounded at the apex, 4-spored, 175–200 by 25–30μ; spores uniseriate, broad-ellipsoid, dark brown, 1-celled, with one large guttule evident when young, smooth, surrounded by a thick hyaline gelatinous envelope 2–2.5μ thick, 40–50 by 19–22μ (exclusive of enveloping sheath); paraphyses numerous, filiform, with granular contents, branched and interwoven at the tips, forming a subgelatinous mazaedium; hypothecium subhyaline, of very loosely formed plectenchyma, becoming darker and more closely interwoven toward the base; outer layer of cells breaking up irregularly and forming a furfuraceous cortex.

Apotheciis erumpentibus, carnosis, subturbinatis vel obconicis, 1–1.5 mm diam., nigris, hymenio fusco, nitenti, rugoso; ascis late-cylindricis, 4-sporis, 175–220×25–30μ; ascosporis uniseriatis, late-ellipsoideis, nigro-brunneis, unicellularibus, 40–50×18–22μ, tunica gelatinosa, 2–2.5μ crassa involutis; paraphysibus numerosis, filiformibus, apice ramosis et intertextis, mazaedium gelatinosum formantibus; hypothecio subhyalino, plectenchymatico, cortice furfuraceo.

In bark of *Betula nigra*, Agr. Campus, Athens, Ga., March 2, 1939, G. E. Thompson and J. H. Miller.

P. magnisporum is related to *P. tetrasporum* (Ell.) Sacc. & Syd., described by Ellis on *Quercus coccinea* from New Jersey as *Dermatea tetraspora*. In the specimen of the latter species examined (Ellis, N. Am. Fungi no. 70), the spores are subspherical, 22–28.5×18–20μ, none reaching even the minimum length of those in *P. magnisporum*. *P. peckianum* Sacc. (11, p. 190) on *Acer* differs in more caespitose apothecia and much smaller asci and spores.

Nannfeldt has pointed out (7, p. 202) (8, p. 92) that several fungi described as *Phaeangium* are in reality species of *Dermatea*, *Pezicula*, and *Velutaria*, the brownish spore coloring being apparently due to age and poor condition of the specimens. This does not seem to be the case, however, in *P. tetrasporum* and *P. magnisporum*, in which the spores are brown in a very early stage, becoming when mature an intense dark brown, similar to the color of *Xylaria* spores. The name *Phaeangium* is therefore retained for the present for these two species, in order to avoid the necessity of naming a new genus.

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ENTOMOLOGY.—*Ten new West Indian scarab beetles of the genus* Phyllophaga, *with two new names.*[1]

LAWRENCE W. SAYLOR, U. S. Bureau of Biological Survey. (Communicated by E. A. CHAPIN.)

The species described as new in this paper further enlarge our knowledge of the relatively numerous species of June beetles known from the West Indies. For the privilege of studying the majority of these new species I am indebted to Dr. E. A. Chapin, of the United States National Museum.

Phyllophaga (Phyllophaga) bimammifrons, n. sp. Fig. 2

Male.—Elongate, shining, glabrous above; head piceous, thorax and legs rufotestaceous, otherwise testaceous above. Clypeus with moderately fine punctures, these dense at center of disk but nearly absent along apical margin of clypeus; clypeal margin slightly reflexed, narrowly and shallowly incised at middle, the angles very broadly rounded; underside of outer apical margin with a single row of punctures, each bearing a long hair, which curves up and back over the clypeal apex. Front with two moderately separated mammilliform tubercles; apical half of disk of the front with fine, sparse, and irregularly placed punctures, basal half of disk and vertex with very dense and extremely fine punctures and several larger intercalated punctures. Antenna 9-segmented, club not quite equal in length to the four preceding segments. Thorax with sides entire, with a few cilia near the apical angles, both hind and fore angles rounded, base and apex with strong, complete margins, punctures of disk of moderate size, rather regularly placed and separated by one to two times their diameters, the center of disk with a small irregular, impunctate area. Elytron with sutural stria obsolete at base and apex, other striae absent; disk subrugose, punctures slightly smaller than those of thorax and less densely placed. Pygidium convex, subrugose, with fine, regularly placed punctures, separated by about two times their diameters and each bearing a short, erect hair. Abdomen convex, polished, fifth sternite sparsely punctured; sixth sternite three-fifths as wide as the preceding, slightly transversely impressed and with fine, moderately dense, setigerous punctures. Claws with a strong median tooth, claw base obtusely dilated.

Female.—Antennal club equal to the three preceding segments; pygidial puncturation somewhat coarser than in male, and disk somewhat tumid before apex; abdomen with the sixth sternite flat. Otherwise as in the male.

Length, 21–23 mm. Width, 11–12 mm.

The type series consists of 12 males and 8 females, 10 from "Sta. Fe, I. de Pines, Cuba, A. R. Otero collector, March 1939 (E.E.A. Cuba Ento. No.

[1] Received February 9, 1940.

11013)" and 10 from the same locality collected March 21, 1939. The *holotype* (U.S.N.M. no. 54014), *allotype*, and designated paratypes are in the United States National Museum; paratypes also have been returned to S. C. Bruner, who kindly sent the series for study, and others have been deposited in the Saylor Collection.

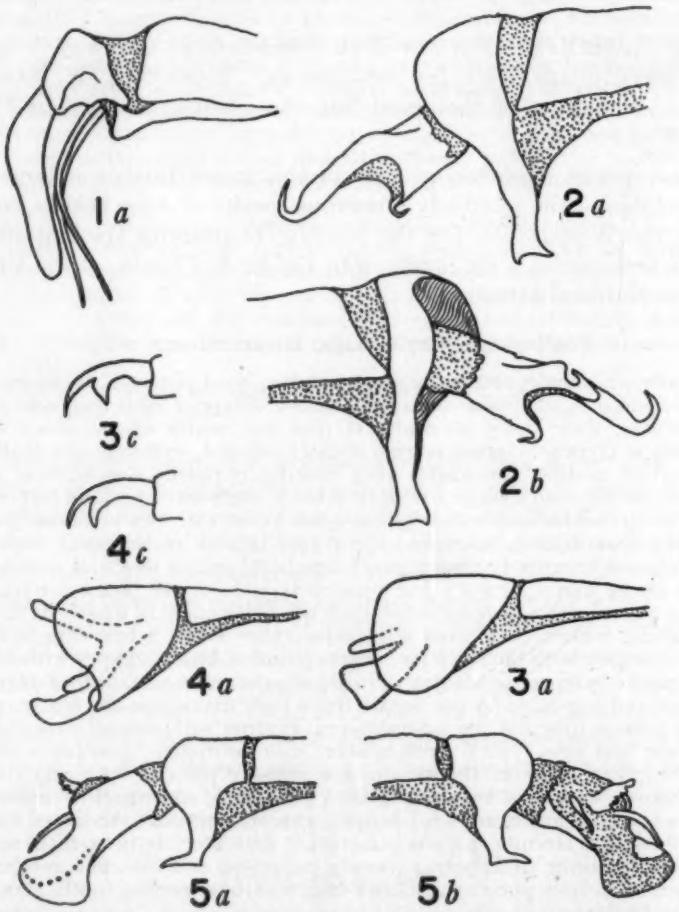


Fig. 1.—*Phyllophaga adjuntas*, n. sp. Fig. 2.—*Phyllophaga bimammifrons*, n. sp. Fig. 3.—*Phyllophaga cneda*, n. sp. Fig. 4.—*Phyllophaga blackwelderi*, n. sp. Fig. 5.—*Phyllophaga bahama*, n. sp. *a*, and *b*, Lateral view of male genitalia. *c*, Tarsal claw.

P. bimammifrons is most closely related to *P. tuberculifrons* (Chev.), with which species it has in common the bimammillate front, but it may be readily separated by the more median tooth of the tarsal claw and the very different male genitalia. In this new species only the females have the smooth

reniform impression adjacent to each eye that Chapin describes for *tuberculifrons;* in the males the area is punctate to the eye margin.

Phyllophaga (Phyllophaga) wolcotti, n. sp. Fig. 10

Male.—Elongate, testaceo-ochreous to testaceopiceous, head and greater part of the thoracic disk piceous, legs rufopiceous; upper surface pruinose, dull, glabrous. Head with clypeus polished, very sparsely punctate, apex narrowly and shallowly emarginate, angles very broadly rounded. Front pruinose, with sparse, small, irregularly placed, umbilicate punctures, vertex and occiput polished and impunctate. Antenna 9-segmented, club oval, equal to or slightly longer than the preceding three segments. Thorax with small, irregularly placed, umbilicate punctures, separated by one to two or more times their diameters; lateral margins entire, angles well marked but obtuse, base entirely margined. Elytron with sutural stria obsolete basally and apically; disk subrugose, with punctures of same size and density as those of the thorax. Pygidium convex, polished, glabrous, with small, moderately dense umbilicate punctures. Abdomen slightly convex, with very fine punctures, glabrous or nearly so at middle, fifth sternite long and with sparse transverse punctures; sixth sternite one-third the length of the preceding, with a deep transverse sulcus, surface hardly punctate. Claws with a strong median tooth, which is long and as strong as the apical one; claw base angularly dilated. Metasternal hairs of moderate thickness. Propygidium strongly polished but with several very minute punctures visible.

Female.—All characters as in the male except that the sixth ventral abdominal sternite is much less strongly impressed and the antennal club is a little shorter.

Length, 23–24.5 mm. Width, 11–12.5 mm.

The *holotype* (U.S.N.M. no. 54015), *allotype,* and 2 paratypes are from "El Yunque, Porto Rico," collected by G. N. Wolcott on April 6, 1939. An additional pair of paratypes are from "Mts. N. of Yauco, P. Rico, IV-20-36, coll. by R. G. Oakley." The holotype, allotype, and a paratype are in the United States National Museum; a pair of paratypes is in the collection of Wolcott, and one paratype has been deposited in the Saylor Collection.

The species is named in honor of G. N. Wolcott, who has contributed much to our knowledge of Puerto Rican melolonthids and who transmitted part of the specimens for description. *P. wolcotti* is most closely related to *P. yunqueana* Chapin, but besides the quite different male genitalia, it may be separated by the darker color, less densely punctate head, nontumid clypeus, and shorter antennal club.

Phyllophaga (Phyllophaga) spinifemora, n. sp. Fig. 6

Male.—Oblong oval, shining, glabrous above; pale testaceous, the head and legs varying to rufotestaceous. Clypeus short, densely punctured, apex widely and moderately deeply emarginate, almost bilobed, angles well rounded, margin hardly reflexed. Front with very dense punctures of moderate size, with or without an indication of a slightly impressed, longitudinal sulcus; vertex polished, impunctate. Eyes rather large. Antenna testaceous, apparently 8-segmented, the fourth segment as long as the second and third combined and widened at the middle; fifth segment one-third as long as the preceding; club equal to funicle in length. Thorax with regularly placed punctures of moderate size, separated by one and one-half to two times their diameters, somewhat closer along the front margin and near sides; sides rounded, angles blunt, lateral margins entire, with very short cilia; hind marginal line absent. Elytron with sutural stria ill-defined, hardly raised,

and punctate; disk subrugose, with moderately dense punctures. Pygidium convex, polished, either glabrous or with a few short and erect hairs, and with regularly placed moderate to rather large punctures, the punctures separated by one to two times their diameters. Abdomen polished, slightly convex; fifth sternite slightly transversely impressed, the apical margin at middle prolonged into a slight though evident lobe; sixth sternite one-third as long as fifth, transversely impressed and punctate. Claws short, with a stuby triangular tooth at the middle. Upper tooth of front tibia well defined. First two segments of hind tarsus equal in length. Hind femur with a single

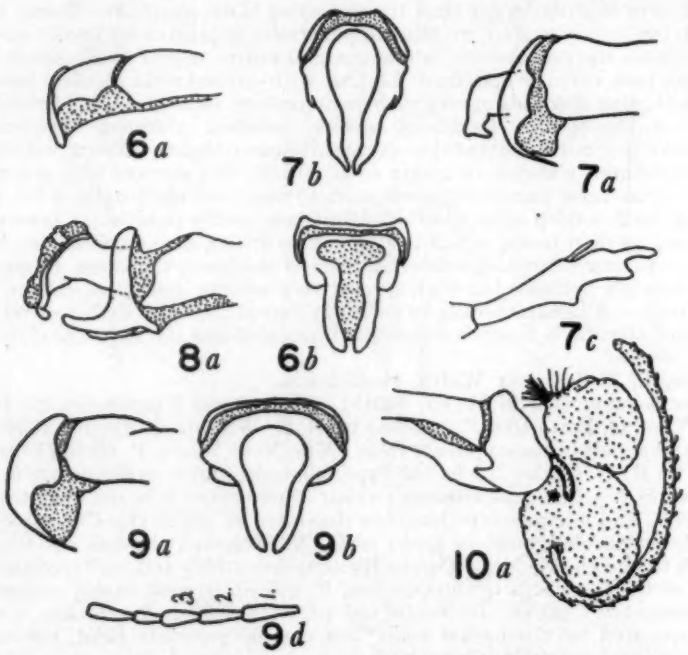


Fig. 6.—*Phyllophaga spinifemora*, n. sp. Fig. 7.—*Phyllophaga manchesterea*, n. sp. Fig. 8.—*Phyllophaga pseudocalcaris*, n. sp. Fig. 9.—*Phyllophaga mandevillea*, n. sp. Fig. 10.—*Phyllophaga wolcotti*, n. sp. *a*, Lateral view of male genitalia. *b*, En face view of male genitalia. *c*, Front tibia. *d*, Dorsal view of front tarsus.

row of 6 to 10 backwardly projecting, short stubby spines well inside of, but parallel to, the hind margin. Spurs free, the longest longer than the first tarsal segment. Metasternum nearly glabrous at center, sides coarsely punctate and the hair very short and scarcely obvious.

Length, 10–10.5 mm. Width, 5–5.5 mm.

The *holotype* (U.S.N.M. no. 54016) and 6 paratypes, all males, were collected by E. A. Chapin and R. E. Blackwelder at Santa Cruz, Jamaica, February 24, 1937, "flying at dusk." The type material, except for a pair in the Saylor Collection, is in the National Museum collection. This species is quite distinct from all West Indian species known to me and is not closely related to any of the known Jamaican species.

Phyllophaga (Phyllophaga) pseudocalcaris, n. sp. Fig. 8

Male.—Oblong-oval, shining; head and elytra with sparse and scattered short hairs, otherwise glabrous above; color testaceous to testaceopiceous, with dark castaneous cloudings on greater part of the head, thoracic disk, and on the elytral apices—entire dorsal surface in some lights with a faint metallic sheen. Clypeus short, almost rounded, but very transverse, apex not reflexed and hardly emarginate, disk densely and somewhat coarsely punctate. Front with moderately coarse, irregularly placed, moderately dense, and variolate punctures. Antenna 9-segmented, testaceous, club ovate and subequal to the preceding four segments in length. Thorax with moderately coarse, somewhat regularly placed variolate punctures, separated by one to three times their diameters; sides roundly dilated, margins entire, with sparse, short cilia; angles blunt, base margined only at sides. Elytron with moderately dense and regularly placed punctures of moderate size, surface smooth, some of the punctures with a very short scarcely obvious hair; an oblique, strialike, impunctate but not raised line on the disk, which is otherwise not striate. Pygidium convex, rugose, with moderately dense punctures, disk apparently glabrous, apex ciliate and subrounded. Abdomen convex, polished; fifth sternite depressed laterally, center of base with a small, ill-defined, and transversely tumid area; sixth deeply and transversely sulcate, disk rugosely punctate. Claws almost like those of *Phytalus* but too widely cleft for that subgenus, the upper claw subapical and as long as, but thicker than, the apical claw; claw base obtusely dilated. Hind spurs free and slender; lower tibial margin immediately adjacent to the shorter spur extended into a short but very obvious pseudospur. First two hind tarsal segments subequal in length. Metasternum nearly glabrous and impunctate at middle, sides moderately densely punctured, the hair short and but little evident. Hind tarsus very slightly shorter than its tibia. Upper tooth of front tibia somewhat distant from the apical two.

Length, 10.5 mm. Width, 6 mm.

The unique male *type* (U.S.N.M. no. 54017) is from Rio San Juan, Dominican Republic, collected by G. S. Miller in March 1938. This species is abundantly distinct from all West Indian species known to me both in the external characters and in the male genitalia.

Phyllophaga (Phyllophaga) blackwelderi, n. sp. Fig. 4

Male.—Oblong oval, polished; testaceous, with the head, thorax, and legs rufotestaceous to piceotestaceous; pygidium, thorax, and elytra apparently glabrous. Clypeus with dense, coarse punctures; apex slightly emarginate, but little reflexed, the angles very broadly rounded. Front with coarse punctures and a few scattered short hairs, the punctures dense in part toward vertex but much sparser in the front half bordering the clypeal suture—vertex impunctate. Eyes large. Antenna 9-segmented, unicolorous testaceous club not quite equal to the funicle. Thorax with strong and entire basal margin; sides roundly dilated, coarsely crenate and with a few cilia in apical half, and entire in basal half; disk with coarse, regularly placed, moderately sparse punctures, the latter separated by one and one-half to three times their diameters; in some specimens the disk has a small and irregular median smooth area; angles obtuse and not well indicated. Elytron subrugose, punctures slightly more dense than on thorax; striae, other than sutural, scarcely indicated, the sutural stria later becoming obsolete before reaching the elytral apex. Pygidium convex, polished, with coarse, regularly placed, moderately dense punctures, the apex rounded and ciliate. Abdomen flat-

tened, polished, fifth sternite with coarse, setigerous punctures; sixth sternite three-fifths the length of fifth, base and apex carinate and the disk transversely flattened and punctate. Metasternum coarsely, densely punctate, the hair short and not very conspicuous. Front tibia tridentate, the teeth approximately equidistant. Hind spurs free and slender, the longest one and one-half times the length of the first tarsal segment, the latter being slightly shorter than the second. Claws widely cleft, approaching closely the *Phytalus*-type; the short but sharp triangular tooth is situated very slightly beyond the middle; claw base roundly dilated. Hind tarsus subequal to the tibia.

Female.—Antennal club equal to the preceding four segments; hind tibial spurs shorter and broader than in male; last segment of abdomen flattened as in male but a little longer, the basal carina broader and less obvious; first segment of hind tarsus a little shorter than in the male and the hind tarsus in some individuals a little shorter than the tibia. Otherwise as in the male.

Length, 9–12 mm. Width, 4.5–7 mm.

The *holotype* male (U.S.N.M. no. 54018) and 4 paratypes are from station 234, Santa Lucia, British West Indies, collected May 15, 1936, by Dr. R. E. Blackwelder. The *allotype* female and 19 additional paratypes have the same locality and collector but were taken at station 205 on March 27, 1936. The types are in the National Museum and designated paratypes are in the Saylor Collection.

The two sexes of this species are surprisingly alike, though they can be separated by giving attention to the details of the antennae, hind spurs, and abdomen. The species is not closely related to any described West Indian species. The only other species described from Santa Lucia is *brevipes* of Froelich (1792), which may not be a *Phyllophaga*, or even a rhizotrogid. In any event, *blackwelderi* differs from it in the femora being elongate and not "ovate-oblong," in the moderately tridentate not "profoundly dentate" front tibiae, and in the marginal base of the thorax, as well as in other details.

Phyllophaga (Phyllophaga) cneda, n. sp. Fig. 3

Male.—Oblong-oval, testaceocastaneous; thorax slightly dull, the beetle otherwise shining above; pygidium elytra, and thorax glabrous. Clypeus short, transverse, with fine and dense punctures; apex moderately reflexed, scarcely emarginate at middle, the whole clypeal margin appearing very nearly semicircular. Front faintly impressed at middle, punctures coarser than those of clypeus, irregularly and rather sparsely placed. Antenna 9-segmented, club very slightly longer than the funicle. Thorax with complete basal marginal line, sides entire and ciliate, angles obtuse and fairly well marked; disk with moderate-sized, regularly placed punctures, separated by one and one-half to three times their diameters. Elytron with sutural stria obsolete apically and nearly so basally, otherwise unstriate; disk subrugose, with moderately dense, regularly placed punctures. Pygidium convex and polished, regularly, moderately densely, but not coarsely punctured. Abdomen slightly convex, polished; fifth sternite plane, sixth three-fourths the length of the fifth, and transversely impressed. Eyes large. Claw tooth situated very nearly at the middle, claw base hardly dilated. Second segment of hind tarsus not longer than the first. Metasternal hairs very short and relatively sparse.

Length, 9.7 mm. Width, 5 mm.

The male *holotype* (U.S.N.M. no. 54019) from Montserrat Island, West Indies, collected by H. G. Hubbard, is in the National Museum. A paratype male, from "Basse Terre, St. Kitts Island, March 26," remains in the Saylor Collection. This species appears to be most closely related to *blackwelderi* Saylor and is considerably smaller than *P. montserratensis* Arrow, the only other known species from the island. From *blackwelderi* the present species may be most easily separated by the strong medium (not subapical) tarsal tooth and also by the slightly different male genitalia.

Phyllophaga (Phyllophaga) bahama, n. sp. Fig. 5

Male.—Subelongate, highly polished; color testaceous, the head, thorax, and legs rufotestaceous to rufopiceous; glabrous above. Clypeus with moderately dense and regularly placed punctures; apex widely and shallowly emarginate, angles broadly rounded, margin slightly reflexed. Front a little more sparsely punctate than the clypeus, the variolate punctures of moderate size. Antenna 9-segmented, club oval and equal to the preceding 4 segments. Thorax regularly, somewhat sparsely punctate, the umbilicate punctures separated by one to three times their diameters; base not margined; lateral margins evenly rounded, with a few cilia, not crenulate; hind angles broadly rounded and indicated only by a very slight point, front angles nearly rectangular. Elytron with sutural stria obsolete basally and apically, otherwise unstriate; disk subrugose, punctures of same size and a little more dense than those of the thorax. Pygidium convex, rugose, the moderately sized punctures dense and regularly placed, surface apparently glabrous. Abdomen convex, polished, nearly glabrous and very finely punctate at middle; fifth sternite with moderately dense punctures, the surface gradually declivous in apical half, which is flattened; sixth sternite three-fifths the length of the fifth, transversely impressed, and the surface very densely and not coarsely punctate. Claw with a short, stubby, median tooth, claw base not obviously dilated. First segment of the hind tarsus varying from as long as, to very slightly longer than, the second. Metasternal hairs moderately dense, but quite short.

Female.—Antennal club equal to either the 3 or 4 preceding segments; pygidium more flattened than in the male, and with or without very short hair; abdomen less convex, with the fifth sternite flat and the sixth slightly convex, the latter finely and moderately densely punctured in the apical three-fifths. Otherwise as in the male.

Length, 14–16 mm. Width, 8–9 mm.

The *holotype* male (U.S.N.M. no. 54020) and *allotype* female, from "Nassau, Bahama Island, West Indies," are in the National Museum. A second pair from the same locality are in the Saylor Collection. Four additional paratypes from "Mangrove Cay, Andros Island, Bahamas, coll. May-June 1917 by Wm. Mann," agree with the types in all respects; one pair of these paratypes is deposited in the collection of the American Museum of Natural History, from whence they came, and the other is in the Saylor Collection.

P. bahama is most closely related to *P. youngi* Cartwright from Florida, but may be separated by the smaller size and the different male genitalia. The close relationship of these two species and the fact that all their characters are closely similar to those of the West Indian type, rather than the mainland type of *Phyllophaga*, give added force to the opinions of both Cartwright and myself that *P. youngi* is not a very old Floridian species but rather a recent immigrant.

Phyllophaga (Phyllophaga) adjuntas, n. sp. Fig. 1

Male.—Subelongate, wider behind; testaceous to rufotestaceous, the thorax and head more rufous; surface shining, head, thorax, and pygidium glabrous. Clypeus with sparse, regularly placed punctures; apex widely and shallowly emarginate, hardly reflexed, angles broadly rounded. Front with moderately dense, irregularly placed punctures, those at the center of apex slightly smaller, vertex impunctate. Antenna 9-segmented, club subequal to funicle, segments 5 and 6 of funicle transverse. Thorax with strong basal margin and wide apical margin; hind angles subrounded, front angles subangulate; disk with moderately fine and umbilicate punctures, separated by one to three times their diameters. Elytron subrugose, punctured like thorax but more densely so, the punctures densest near base. Pygidium convex, polished, fifth sternite with several coarse setigerous punctures at center. Sixth abdominal sternite a little shorter than the fifth, the basal half being a smooth but nearly flat process, widest at the middle where it is suddenly interrupted, thus forming two very blunt and dentate lobes; surface between apex, and basal and apical processes, transversely impressed and with fine punctures and sparse erect hairs, the entire sternite with a faint suggestion of a median longitudinal sulcus. Claw tooth a little stronger than apical one and situated a little beyond the middle, claw base obtusely dilated. Metasternal hair of moderate length and density. First two segments of hind tarsus subequal in length.

Female.—Antennal club equal to or slightly longer than the preceding 4 segments; sixth abdominal segment slightly convex, with fine and not dense setigerous punctures; first segment of hind tarsus shorter than the second. Otherwise as in the male.

Length, 13–15 mm. Width, 6–7 mm.

The *holotype* male from Isolina, Puerto Rico, collected on April 16, 1901, is in the United States National Museum (U.S.N.M. no. 54021). The *allotype* female and a paratype male, both from Adjuntas, Puerto Rico, collected May 2, 1917, at the "Fed. Exp. Station, Acc. no. 49, 1917," are in the American Museum of Natural History, whence they came as a loan for study.

P. adjuntas does not resemble closely any known West Indian species in the type of male genitalia; externally it resembles *P. citri* Smyth but differs from that species in the nonpruinose dorsal surface, the much longer male antennal club, and the quite different male sixth abdominal segment.

Phyllophaga (Phyllophaga) mandevillea, n. sp. Fig. 9

Male.—Rufocasteneous; polished and glabrous above. Head with front convex and with a suggestion of a median longitudinal sulcus, and with rather coarse, variolate, and somewhat sparse punctures. Clypeus very short and transverse, the apical margin narrowly and very strongly emarginate, the emargination in connection with the strongly rounded angles giving the clypeus a distinctly bilobed appearance; disk coarsely and not densely punctate. Eyes large. Antennae 8-segmented, the club very slightly longer than the funicle; fourth segment twice the length of third, fifth segment transverse and about one-fourth as long as fourth. Thorax with the disk variolately punctate, the punctures moderately coarse but sparse, and separated by two or three times their diameters on the center of the disk, but closer at sides; base of thorax not margined at middle, front margin very weakly indicated but entire, sides roundly dilated and entire, with sparse and very short cilia; front and hind angles obtusely subangulate.

Scutellum impunctate. Elytron with coarse, variolate punctures, surface unstriate and subrugose; sutural stria not well indicated at middle and entirely obsolete basally and apically. Pygidium strongly convex, pruinose, with moderately dense, fine punctures, and short erect hair; apex subtruncate and ciliate. Abdomen polished, flattened at middle, coarsely punctured, and with sparse short hairs; fifth sternite slightly longer than fourth, middle of the apical margin with two sharp but short teeth separated from each other by a shallow emargination; sixth sternite as long as fifth, surface rugose, flattened, with coarse punctures and slightly carinate basal and apical marginal lines, each bearing a single row of rather long hairs. All claws short with the apical tooth rather strongly curved; middle tooth small, situated slightly basad from the middle and strongly inclined toward the base; basal dilation obtusely rounded. All tarsal segments with moderately dense hairy soles; first segment of each tarsus longer than the second. Front tibia strongly tridentate, the upper tooth slightly beyond the middle. Metasternum strongly, very densely, and umbilicately punctate, with very short procumbent hair; somewhat more sparsely punctate at middle. All tarsi longer than their tibiae. Apex of middle tibia with a strongly serrate margin; each lateral angle of the apex is somewhat prolonged into a slightly larger tooth.

Female.—Antennal club ovate, hardly equal to segments 3 to 5 combined; eyes smaller; clypeus larger than in male; pygidium more narrowed apically and the hairs longer; abdomen semiconvex and very coarsely punctate, with the apical margin of the fifth sternite plane; sixth abdominal segment slightly convex; hind tarsus distinctly shorter than the tibia; all other characters including the middle tibia, exactly as in the male.

Length, 11.5 to 13.5 mm. Width, 5.5 to 6.5 mm.

The *holotype* male, the *allotype* female, and a pair of paratypes are from Mandeville, Manchester, Jamaica, collected between November 16 and December 19, 1919, at altitudes between 2,131 and 2,250 feet. The holotype and allotype are deposited in the American Museum of Natural History and the paratypes in the Saylor Collection.

This species is most closely related to a species (from exactly the same locality in Jamaica) that is now in manuscript by M. W. Sanderson. From this species of Sanderson's the new species differs especially in having the third tarsal segment two and one-half times longer than wide (rather than only one-half longer than wide), the elytral punctures finer and evenly spaced (not confusedly punctate), the hairy "sole" of the tarsus much less dense, and the slightly different male genitalia. I am indebted to Dr. Sanderson for comparing my specimens with the type of his new species.

Phyllophaga (Phyllophaga) manchesterea, n. sp. Fig. 7

Male.—Castaneous, shining, glabrous above. Head with front very coarsely, densely and variolately punctured, with a strong median, impressed, longitudinal sulcus. Clypeus short, the apex reflexed, narrowly and deeply emarginate and the angles rounded, the entire clypeus appearing bilobed; disk coarsely punctate. Antenna 8-segmented, club subequal to funicle; segments 3 and 4 moderately long, the fourth slightly longer than the preceding; fifth transverse. Thorax with disk variolately punctate, the punctures moderately coarse and separated by one to two times their diameters on the disk, much closer at sides and nearly contiguous at center of apex; base not margined at middle; front with strong marginal lines; sides roundly dilated, entire; angles obtrusely subangulate. Scutellum with several coarse

punctures. Elytron rugose, nonstriate on disk, the punctures coarse, variolate, and moderately dense, sutural stria obsolete basally and apically. Pygidium convex, slightly pruinose, with moderately dense and very coarse punctures, and apparently glabrous except for the row of hairs at apex. Abdomen slightly flattened, coarsely punctate, with scattered short hairs; fifth sternite coarsely punctate, apical margin evenly rounded; sixth sternite half as long as fifth, and transversely impressed. All claws of moderate length, each with a very small median tooth. Hind tibial spurs free, the longest longer than the first tarsal segment. First segment of hind tarsus shorter than the second; in the front and mid tarsi the first segment is equal in length to the second. Metasternum coarsely and very densely punctate at sides and very sparsely so at center, with short and hardly obvious hair. Front tibia tridentate, the upper tooth slightly beyond the middle in postion; the middle tooth is distinctly closer to the apical than to the basal tooth.

Length, 9.5 mm. Width, 4 mm.

The unique male *type* is from Mandeville, Manchester, Jamaica, collected November 30 to December 4, 1919, at an altitude of 2,131 feet, and is deposited in the collection of the American Museum of Natural History, from where it was lent for study by Dr. R. E. Blackwelder.

P. manchesterea is nearest *P. mandevillea* in general relationships but differs especially in the smaller size, tarsal claws, much less pilose tarsi, pygidial and abdominal characters, and the coarser and denser puncturation. From Sanderson's new species it differs especially in having a median tarsal claw tooth that the former lacks.

NEW NAMES

Whereas the name *Listrochelus* can not be maintained as a genus by any set of characters yet discovered[1,2] and must be considered as a subgenus of *Phyllophaga*, several specific names become homonyms, and new names are needed. Two are here proposed:

Phyllophaga (Phyllophaga) temaxa, new name

Lachnosterna parilis Bates, Biol. Cent. Amer. **2**(2): 404. 1889. (Non *Listrochelus parilis* Bates, 1888, l.c., p. 172.)

Phyllophaga (Listrochelus) yaqui, new name

Listrochelus debilis Arrow, Ann. Mag. Nat. Hist. (ser. 10) **11**: 145. 1933. (Non *Gynnis debilis* LeConte, 1856, non *Lachnosterna debilis* Horn, 1885.)

[1] SAYLOR, L. W. *Necessary changes in important rhizotrogid genera.* Rev. Ent. **7**: 318–322. 1937.

[2] SAYLOR, L. W. *Revision of the beetles of the melolonthine subgenus* Phytalus *of the United States.* Proc. U. S. Nat. Mus. **86** (3048): 157–167. 1939.

MALACOLOGY.—*A new urocoptid mollusk from Mexico.*[1] HARALD A. REHDER, U. S. National Museum.

Among some mollusks from the State of Nuevo Leon, Mexico, sent to the United States National Museum by E. J. Koestner, was an interesting new urocoptid, which was determined to be related to *Propilsbrya* Bartsch.

This group was created by Dr. Paul Bartsch in 1906[2] as a subgenus of *Epirobia* to include a single species *Epirobia* (*Propilsbrya*) *nelsoni* Bartsch, from the Sierra Guadalupe, Coahuila, Mexico. It differs radically from *Epirobia* in having a broader axis, an axial lamella, and a denticulate parietal lamella; moreover, it is far out of the range of the more southerly *Epirobia*. In the same publication, on page 151, Bartsch defined a new subgenus of *Holospira* under the name *Stalactella*, for the species *Holospira* (*Stalactella*) *rosei* Bartsch, from Tehuacan, Puebla, Mexico. This species has the same type of lamellae as found in *Propilsbrya* and has the same general form, but is decollate. In this group, however, the presence or absence of the early whorls is apparently not a differentiating character, as the first four or five whorls seem to be readily detachable. Among the 11 specimens of the present new species that I have been able to examine, two had the apical whorls still adherent, and in one of these the first 4 or 5 whorls dropped off during the examination of the specimen.

We therefore may unite *Propilsbrya* and *Stalactella*, retaining the first name as the generic designation for the group in question and placing it near *Holospira*, from which it differs in being slenderer and decollate and in possessing denticulate lamellae.

The shell submitted by Mr. Koestner is related to *Propilsbrya* (*Stalactella*) *rosei*, differing from it in the internal armature. For this species I propose the following new subgenus:

Pectinistemma, n. subgen.

Shell of moderate size, axially ribbed, with the nuclear whorls usually deciduous. An axial lamella is present, originating anteriorly as a cord and gradually becoming broader and more lamellar, furnished in the third and fourth whorls from the last with long, flattened, rather crowded, forward-curving teeth. A strong parietal lamella is also present, originating in the fifth whorl from the last, and in the next two whorls scalloped, or bearing crowded, short, broad, flattened, forward-curving teeth.

Type.—Propilsbrya (*Pectinistemma*) *koestner*, new species.

This subgenus differs from typical *Propilsbrya* in the axial lamella being thin and bearing denticles and in the teeth of the parietal lamella being

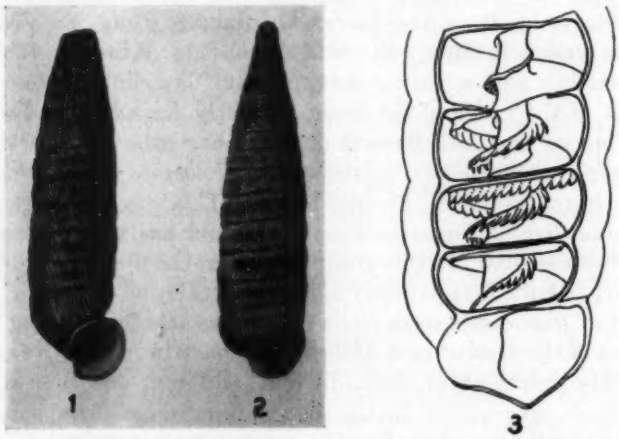
[1] Published by permission of the Secretary of the Smithsonian Institution. Received March 9, 1940.

[2] BARTSCH, PAUL. Proc. U. S. Nat. Mus. 31(1483): 121. 1906.

broader and more crowded, forming almost a thin, pendant, platelike lamella.

Propilsbrya (Pectinistemma) koestneri, n. sp. Figs. 1–3

Shell of moderate size, slender, cylindrical, gradually tapering at the apex, vinaceous-brown to bluish gray in color. The nuclear whorls about 3, rather smooth, somewhat bulbous, the following $18\frac{1}{4}$ whorls rather flattened, strongly impressed at the suture, rather closely axially ribbed. The first 5 whorls are easily detachable and generally lost, so that the shell is decollate, with the minute round perforation of the hollow axis visible from



Figs. 1–3.—*Propilsbrya* (*Pectinistemma*) *koestneri*, n. sp. Fig. 1.—Holotype, ×3. Fig. 2.—Paratype, immature, showing nuclear whorls, ×3. Fig. 3.—Internal view, showing lamellae, ×7.

above. The base is evenly rounded, the axial ribs continuing into the minute umbilical perforation. The aperture is oval, the posterior portion somewhat flattened, and the lip entire, slightly reflexed. The lamellae are adequately described in the subgeneric diagnosis above. Both lamellae terminate just behind the aperture and hence are not visible from the exterior, the columella showing only a slight axial swelling.

The type, U.S.N.M. no. 535762, was collected by R. A. Schneider and E. J. Koestner on the Cerro Potosi at Galeana, State of Nuevo Leon, Mexico. Here it was hanging on mosses under rock outcroppings at an elevation of 12,000 feet. It, a decollate specimen, measures: Height, 17.4 mm; width, 5.0 mm.

Seven other specimens, U.S.N.M. no. 535763, are from the same lot.

Three further specimens, U.S.N.M. no. 467392, were received some years ago from Dr. S. S. Berry. They were collected by S. Dickin on the north slope of Cerro Potosi at an elevation between 10,000 and 11,000 feet.

From *Propilsbrya rosei* Bartsch, described from Tehuacan, Puebla, this species differs externally in color and in the axial riblets being stronger and more crowded. It is, moreover, a larger, stouter shell, and the apical whorls are slenderer and attenuated. From *Propilsbrya nelsoni* Bartsch it differs in being a stouter shell with more flattened whorls.

PROCEEDINGS OF THE ACADEMY AND AFFILIATED SOCIETIES

THE ACADEMY

360TH MEETING OF THE BOARD OF MANAGERS

The 360th meeting of the Board of Managers was held in the Board Room of the Cosmos Club on Friday, April 19, 1940. President CRITTENDEN called the meeting to order at 8:02 P.M. There were 19 present, as follows:

E. C. CRITTENDEN
F. D. ROSSINI
F. C. KRACEK
H. S. RAPPLEYE
G. STEINER
F. M. SETZLER
W. B. BELL
A. T. MCPHERSON
C. THOM
W. A. DAYTON
H. L. CURTIS
W. RAMBERG
E. W. PRICE
C. L. GARNER
H. G. DORSEY
C. L. GAZIN
W. W. DIEHL
and by invitation:
J. H. KEMPTON
R. J. SEEGER

The customary reports of the standing committees were read and accepted. H. L. CURTIS, chairman of the special committee, charged with recommending to the Board the appropriate action to be taken with respect to amending the bylaws on the subject of the offices of nonresident vice-presidents, reported his committee in disagreement but with the possibility of accord by the next meeting of the Board.

M. W. STIRLING was elected by the Board to fill the vacancy caused by the resignation of J. F. COUCH who had been elected manager at the last election.

President CRITTENDEN was authorized to appoint delegates from the Academy to the Fiftieth Anniversary celebration of the Ohio Academy of Sciences at Columbus, Ohio, May 9–11, and to the Eighth American Scientific Congress at Washington, D. C., May 10–18. He was also authorized to appoint two committees—one to consider Societies eligible for affiliation with the Academy and the other to consider the question of a meeting place for the Academy when the Cosmos Club leaves its present quarters.

The Board adjourned at 10:02 P.M.

ANTHROPOLOGICAL SOCIETY

The Anthropological Society of Washington at its annual meeting held January 16, 1940, elected the following officers for the ensuing year: President, FRANK M. SETZLER; Vice-president, JULIAN H. STEWARD; Secretary, REGINA FLANNERY; Treasurer, T. DALE STEWART; members of the Board of Managers, GEORGE S. DUNCAN, HERBERT W. KRIEGER, JULIAN H. STEWARD, RUTH UNDERHILL, WALDO R. WEDEL.

A report of the membership and activities of the Society since the last annual meeting follows.

Membership:

Life members	2
Active members	39
Associate members	11
Total	52
New members	5

The members elected during the year were: WILLIAM N. FENTON, ANTONIO SANTA CRUZ, and HELEN CULLINANE, active members; WALTER BART GREENWOOD and JOSEPH R. SINGER, associate members.

The Treasurer's report is as follows:

Funds invested in Perpetual Building Association (Interest for 1939 not included)		$1,453.42
21 shares Washington Sanitary Improvement Co. par value $10 per share		210.00
2 shares Washington Sanitary Housing Co. par value $100 per share		200.00
Cash in bank		576.62
		$2,440.04
Bills outstanding:		
To American Anthropological Association	$80.00	
To printer	3.75	
To Treasurer	1.93	
	$85.68	85.68
Total		$2,354.36
Total as of 1/16/39		2,171.76
Increase		$ 182.60

Papers presented before the regular meetings of the Society were as follows:

January 17, 1939, 683d meeting, JOHN M. COOPER, *Are the simplest living cultures representative of early prehistoric cultures?*

February 21, 1939, 684th meeting held jointly with the Smithsonian Institution on the occasion of the Eighth Arthur Lecture, HERBERT J. SPINDEN, *Sun worship.*

March 21, 1939, 685th meeting, WILLIAM E. CADIEUX, *The Blackfoot Indians of Montana.*

April 20, 1939, 686th meeting, held jointly with the Washington Academy of Sciences, W. M. KROGMAN, *The skeleton tells its story.*

October 17, 1939, 687th meeting, W. W. HILL, *Economic history of the Navaho Indians.*

November 21, 1939, 688th meeting, DAVID C. GRAHAM, *The customs and myths of the Ch'uan Miao of southwest China.*

December 19, 1939, 689th meeting, JOHN R. SWANTON, *De Soto's route through the Southeast.*

REGINA FLANNERY, *Secretary*

BOTANICAL SOCIETY

293D MEETING

The 293d regular meeting was held in the assembly hall of the Cosmos Club, December 6, 1938, President GRAVATT presiding; attendance 70. ROGERS MCVAUGH, BRITTAIN B. ROBINSON, MARCUS M. RHOADES, DANIEL SULLIVAN, and CLAUDE HOPE were elected to membership.

Notes and reviews.—M. B. WAITE called attention to the scarlet oak, which still showed a brilliant red coloring while the usual autumnal coloring was about October 10. He also displayed a plant of Mammoth Maryland tobacco in flower which had survived two heavy frosts. The tobacco crop had been harvested about the first of September. CHARLES THOM exhibited a new book, *Introduction to industrial mycology*, by George Smith.

Program.—PERKINS COVILLE: *Prairie shelter belt work of the U. S. Forest Service.*

38TH ANNUAL MEETING

The 38th annual meeting was held immediately following adjournment of the 293d regular meeting, G. F. GRAVATT presiding.

James F. Couch read an obituary for V. K. CHESNUT; John A. Stevenson for B. T. GALLOWAY; Charles E. Chambliss for FRANK LAMSON-SCRIBNER; H. P. Barss for FRED C. MEIER; C. E. Leighty for GUY N. COLLINS. EMMA F. SIRRINE was elected to honorary membership.

The following officers were elected for 1939: President, CHARLES THOM; Vice-President, CHARLOTTE ELLIOTT; Recording Secretary, ALICE M. ANDERSEN; Corresponding Secretary, NELLIE W. NANCE; Treasurer, KENNETH B. RAPER. Nominated for Vice-President of the Washington Academy of Sciences, G. F. GRAVATT.

294TH MEETING

The 294th regular meeting was held in the assembly hall of the Cosmos Club, January 3, 1939, President CHARLES THOM presiding; attendance 90. HARRY HUMFELD was elected to membership.

Notes and reviews.—M. B. WAITE called attention to the fact that many tree seeds require a resting period before they will germinate, but that he had observed that the acorn of the rock chestnut oak does not require a resting period and germinates immediately upon falling to the ground. In November the roots of the seedlings were 6 inches long.

Program.—W. M. LUNN, D. E. BROWN, J. E. MCMURTREY, and W. W. GARNER: *Tobacco and weeds.*—It was soon observed in colonial days that virgin soil produced good yields of tobacco and that the leaf had a finer texture and lighter body, better suited to the market demands of the period, than that grown on the older cultivated areas. The same holds true at the present time. Consequently, in order consistently to produce the desired type of leaf the early settlers and their successors continued to clear the forested areas until in time most of the land suited to tobacco in the older tobacco-producing regions had been brought into cultivation. Subsequently, crop rotation and the use of manures and fertilizers have been tried in an effort to maintain yields and quality on old land but these practices have not proved satisfactory on all soils and with all crop combinations.

It is clearly evident from the results presented that tobacco that is fertilized intelligently and grown after natural weed fallow of sufficient duration possesses in a large measure those characteristics which were early observed in the crop grown on virgin land. The crop grown after bare fallow has shown a rapid decline in yield and gross value, demonstrating that the cover of spontaneous vegetation is the keystone of the system rather than simply allowing the land to remain idle.

The tests conducted with individual weed and crop plant species have consistently shown that certain species are much more desirable than others. Ragweed and horseweed as the preceding cover crop have produced marked

increases in yields and especially in values of the tobacco crop over results obtained from bare fallow. On the other hand, following lamb's-quarters the tobacco crop has actually shown reductions in yields and value as compared with bare fallow. In these tests annual lespedeza has shown no advantage as a cover crop to precede tobacco, sweet clover, rabbit's-foot clover, and wild pea have not always shown a decided advantage, while partridge pea has produced some increase in yield. While the natural weeds occurring in these tests consisted principally of those species in pure stands which produced high quality leaf, it is possible that the ones found to be objectionable might predominate under some conditions, with a resulting harmful effect on the succeeding tobacco crop. It is hardly to be expected that a given weed species would have the same effect on tobacco on all soils or under all conditions.

The general beneficial effect of the weed fallow was the promotion of a quick start and very rapid and uniform growth of the tobacco plants from transplanting time to maturity. Within normal limits this result is, in turn, associated with a uniformly high market value per acre and average price per pound which demonstrates that the resulting product meets current demands for most manufacturing purposes.

J. H. MARTIN: *Cleaning 20 million bushels of seed grain* (lantern).—Average grain from the spring-wheat States contains more than 2 percent by weight of weed seeds, chiefly wild oats, mustard, and pigeon grass. Nearly 20 million bushels of Government-owned wheat, oats, barley, and flax were cleaned for seeding in drought-stricken areas in 1934–35. Seed separation by mechanical means is possible when the seeds differ appreciably in specific gravity, length, or thickness. The most complete separations are accomplished by means of pocketed discs or indented cylinders when seeds differ in length. Suction separates better than air blasts. Mustard seeds roll over screen perforations and are difficult to separate completely from grain. Quackgrass seeds could not be separated completely from oats or flaxseed. Mechanical cleaning increased the test weight of wheat slightly, barley considerably, and oats remarkably, but reduced that of flaxseed by roughening the seed coats and preventing close packing.

ALICE M. ANDERSEN, *Recording Secretary.*